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THE OHIO JOURNAL OF SCIENCE

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THE LYCOPODIACEAE OF OHIO

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Since the publication of a map of the Lycopodiums of Ohio by Griggs[1] in 1913, there have been many more specimens collected, considerably extending the range of some species.

The present paper is a report based upon specimens in the Ohio State Herbarium, Field Museum Herbarium, and that of the author.

On the whole, with a few exceptions, the range of all the species of Lycopodium in the state follows very closely the phytogeographic regions as set by Schaffner. Of these regions, the most important for our purpose is the Allegheny Plateau in the eastern portion of the state, which is divided into three main parts.[2]

Of the seventy-one different localities in which one or more species of Lycopodium have been collected in Ohio, sixty-two are located in the Allegheny Plateau region, and they are about equally well distributed in both the glaciated and non-glaciated portions.

The nine remaining localities are scattered over the central and north-western sections of the state which are not located in the Allegheny Plateau.

Perhaps by careful searching where conditions are favorable, more localities can be found where Lycopodiums may be collected to still further extend the range of some species.

Let us now consider separately, each individual species found in Ohio.

Lycopodium lucidulum Michx. is perhaps the best known and most widely collected species in the state. Its occurrence is mainly on the

[1]Observations on the Geographical Composition of the Sugar Grove Flora, Griggs, 1913.

[2]Revised Catalog of Ohio Vascular Plants, Schaffner, 1932.

Allegheny Plateau, but it has been listed from Allen, Champaign, Clark, and Fulton counties.

Lycopodium porophilum, L. & U.—The typical habitat of this species is cool, shaded, sandstone cliffs such as one finds in the gorges and caves of Hocking county and it should be looked for wherever such conditions occur. It has never been collected in Ohio outside the Allegheny Plateau regions.

Lycopodium inundatum L.—This species does not confine itself to any one region, but grows wherever conditions are favorable, usually in wet, sandy places and is often associated with sphagnum moss. It has been collected in Knox, Portage and Trumbull counties and is frequently found in the Oak Openings of Lucas and Fulton counties.

Lycopodium obscurum L.—Fairly well distributed in the northern and southern Allegheny Plateau regions and is also very often found in the Oak Openings. I have not separated variety *dendroideum* (Michx.) D. C. Eaton.

Lycopodium clavatum L.—Known from nine counties in Ohio and entirely from the Allegheny Plateau regions. Several varieties of this species have been described but due to the fact that not many of the specimens studied had mature fruit, it was deemed advisable to treat them all under the specific name alone.

Lycopodium tristachyum Pursh.—This species is not as well known or as common as some, but once it is distinguished it is never mistaken for any other. In Ohio it has been collected from Ashtabula, Fairfield, Hocking, and Licking counties. The localities are all within the boundaries of the Allegheny Plateau.

Lycopodium complanatum L.—Next to *L. lucidulum*, this is the most widely collected species in the state and also is found only in the Allegheny Plateau regions.

Lycopodium complanatum, var. *flabelliforme* Fernald.—Only one specimen has so far been identified as being this variety. However, the difference is so slight that it may be easily overlooked. The specimen which I have was collected near Swanton, Fulton county, in 1925. During the summer of 1933 I visited the same locality but was unable to find it again.

KEY TO THE LYCOPODIUMS OF OHIO[3]

A. Sporophylls not different from foliage leaves, not in a terminal spike or strobilus....................B.
A. Sporophylls different from foliage leaves, in a terminal strobilus..........C.
B. Leaves broadest above middle, distinctly serrate; plants regularly, dichotomously branched....................*L. lucidulum*
B. Leaves sometimes broader at base, very slightly or not at all serrate; plants erect, dichotomous but branching more frequently.....*L. porophilum*
C. Sporophylls rather herbaceous....................*L. inundatum*
C. Sporophylls scale-like....................D.
D. Strobilus sessile, plant tree-like....................*L. obscurum*
D. Strobilus peduncled....................E.
E. Leaves linear, awl-shaped....................*L. clavatum*

[3]Key adapted from Wilson—Preliminary Reports on the Flora of Wisconsin, IV.

E. Leaves scale-like...... ....F.
F. Branches with constrictions .. .. G.
F. Branches without constrictions, fan-shaped, 1–3.5 mm. wide; ventral median leaves much reduced ....*L. complanatum* var. *flabelliforme*
G. Branches 1–1.5 mm. wide, rather squarish; ventral median leaf reaching or overlapping the one above; plant glaucous..... ....*L. tristachyum*
G. Branches 1–3 mm. wide, flattened; ventral median leaves much shortened, on the older branches not reaching the one above..........*L. complanatum*

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Prehistoric Chinese

Little did we think that when J. Gunnar Andersson went to China in 1914 as Advisor to the Chinese Government on Mining that twenty years later we would see him in the light of a discoverer of the first definite records of fossil man in Asia, north of the Himalayas. It is a far cry from the discovery and exploration of the Yen Tung Shan iron ores to the little cave some 37 miles southwest of Peiping which he heard contained "dragon bones." This cave, known as Chou K'ou Tien, yielded the now famous Pekin Man, so ably described by the late Davidson Black under the name **Sinanthropus pekinensis.** This discovery came about in a most natural way. Andersson had become interested in the well known Chinese medicine "Dragon Bones"; trailing down their source he found the deposits where they were preserved as fossils, finding there the first dinosaur from a definite locality. From that time on any deposits which contained dragon bones were searched. This lead him to the cave and the discovery of the Pekin Man.

In his eleven years of traveling in China, the loess, or as the Chinese call it, the Huang T'u (Yellow Earth), that great blanket of yellow earth which covers much of China, drew him to a study of what it had hidden away in its beds. Here he found below the loess some Paleolithic sites and at or near the top some Neolithic sites as well.

It is impossible to do justice to the great mass of information packed between the covers of this book in a review. As a geologist the author gives us a very complete summary of the geology of China for the regions he discusses. Included in this are his contributions and discoveries as well. The careful use of illustrations increases the usefulness of the book.

Our thanks to Professor Andersson for giving us a not too technical taste of the great amount of work that he was able to accomplish during his time in China. The publishers, too, have done their part well in giving us this interesting book on the ancient men of China.—WILLARD BERRY.

Children of the Yellow Earth. Studies in Prehistoric China, by J. Gunnar Andersson. Translated from the Swedish by Dr. E. Classen. 345 pp. New York: The Macmillan Co., 1934.

ECOLOGICAL OBSERVATIONS ON *AMBYSTOMA OPACUM*

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Several reports dealing with the life history of *Ambystoma opacum* Gravenhorst have appeared, among which are the works of Mann (1855), Deckert (1916), Dunn (1917), Brimley (1920), Bishop (1924), Lantz (1930), Noble and Brady (1930 and 1933). The species has been found in scattered areas over Ohio, but no previous studies concerning its breeding habits within the state have been published. In studying the ecology of certain upland forest areas in southwestern Ohio this species was encountered several times and its nesting sites located. The observations made to date seem to be of sufficient interest to justify this report. Physiological studies have been carried on in the laboratory as a means of further analyzing the conditions found in nature.

NESTING

Ambystoma opacum, in southwestern Ohio, inhabits what are known locally as "swamp forests." These forests are located on upland flats of impervious soil from which the water drains very slowly. The forests differ in their degree of development from the pin-oak to a nearly pure beech forest. Combinations of white elm, red maple, hickories and gums are found in the different stands. The herbaceous story is limited. Tree roots crowd to the surface, indicating a soil that is saturated with water a considerable portion of the year. In this type of environment I have found this salamander in Clinton county near Villar's Chapel, in Warren county along the earthworks at Fort Ancient and in an oak-hickory forest in the southwestern corner of the county, and in Clermont county near Goshen Station.

Adult salamanders are found most commonly in the months of September and October. The species is rarely met with at other times. Clues which led to the discovery of the nests were the finding of the larvae in certain pools in the spring of 1932 and 1933, and the observations of Noble and Brady

(1933). These authors state that "*Ambystoma opacum* lays its eggs under leaf mold, sphagnum, dry water weed or other cover in situations which will be flooded by the winter rains." Mann made the first observations on the breeding habits of this species at Gloucester C. H., Virginia, in 1854. He wrote the following description: "The localities are beds of small ponds in the woods, which in rainy seasons have water in them. . . . The nests . . . were in a small hollow in the surface of the earth, deeply covered with leaves, and under which were tunnels extending in all directions. In these hollows the animals were . . . curled up over their eggs." Not all parts of the wooded areas offer suitable breeding grounds, but only certain depressions, either natural or artificial, are chosen for the nests. Only one nest was found under an inverted half of a hollow log. All others were beneath leaf litter. Mouse or crayfish tunnels are utilized, but many nests show no connection with other excavations and must be made by the female salamander. The male has not been observed to have any part in nest building. The nests are readily found by turning the over-lying litter with a small hand rake. They measure three to four inches in diameter and are from one to two inches deep. The nests are usually not in the dampest part of the depression, but along the margins of the low banks or on a raised portion of the pool floor. Adequate cover is essential as a concentration of nests in the most favorable places shows. Some moisture is required, but as shown below too much water favors premature hatching.

The time of egg laying was not exactly determined, but chiefly occurred between September 27 and October 5. This was ascertained from the development of eggs laid in the laboratory by a female salamander collected October 6. This animal was placed in a box containing moist sand covered with moss. She hollowed out a small area beneath the moss and laid 81 eggs on October 8. Six days were required to reach the degree of development possessed by eggs collected October 10. With few exceptions all the eggs collected did not vary more than five days in their degree of development. Twenty-five nests were observed and counted. The average number of eggs was 98 per nest. Egg counts of individual nests were 120, 91, 85, 90, 80, 69, 155, 112, 87, 147, 73, 104, 89, 116, 69, 150, 116, 99, and 99. There was also one double nest with 174 eggs and a combination of four nests which averaged

84 eggs each. A second counting, 66 days after the first, was made on four nests in the field.

NEST NUMBER	1	2	3	4
Number of eggs, October 13.. . ..	147	69	87	155
Number of eggs, December 18	141	53	70	134

The average loss was slightly over 10%. Eggs which have failed to develop can be recognized by their discoloration. These were not included in the second counting. A number of the eggs are no doubt destroyed by beetles and centipedes which are common visitors in the nests.

In agreement with earlier writers and contrary to Noble and Brady (1933), I have always found the female on top of the eggs. Her tail may be curled or straight, but her body invariably rests on the egg clutch. The accompanying photograph shows this clearly. Variation in the length of time that the female stays with the eggs has been found. When the females are separated from the nests during the counting of the eggs they usually lie quietly on the leaf litter, making no effort to escape. After being returned to their nests they may or may not continue to brood the eggs. Four of seven females were found to be still brooding their nests after a temporary removal. One female was disturbed for photographing twice but stayed with her nest two weeks longer. Females were brooding undisturbed nests November 6, about one month after egg laying, but had left a month later, December 6. All females whose nests were disturbed left before November 6. The eggs have a coating of soil adhering to them. Since not all are in contact with the soil at one time it appears that the female must burrow through the eggs, changing their position. Her body is free from dirt. In deserted nests many of the eggs become matted together. Such clumps have a low percentage of development. Males are occasionally found in the nesting area after egg laying, but are usually scattered in the vicinity of the nesting grounds.

HATCHING

It was found that the growth of the embryo follows very closely the growth stages of *Ambystoma maculatum* as figured by R. G. Harrison (1925). Consequently the "Harrison

Stages" are used in recording the early growth of *Ambystoma opacum* larvae. Laboratory experiments were conducted to determine the percentage of eggs capable of hatching and the ages at which hatching occurs. From a total of 220 eggs immersed in water, 182, or 80% (Table I) hatched.

It was found that it is not always necessary for an egg to be immersed in water in order to hatch. After heavy rains, insufficient to flood the nest but moistening it, some larvae will hatch. This was observed in the field December 18 and again January 8. The larvae emerging under these conditions perish if the rainfall is insufficient to provide permanent inundation.

TABLE I

HATCHING EXPERIMENTS

All larvae except those in nest 3 were placed in fingerbowls in tap water in the laboratory. The eggs in number 3 rested in a depression made in tightly packed clay. These eggs were kept outdoors. Rains covered the eggs to a depth of one-half inch between October 27 and 30. Eighty of these 100 eggs hatched during the three days of exposure. Five more hatched during the following week.

NUMBER OF THE NEST	1	2	3	4	5	6
Number of eggs	12	25	100	25	48	10
Number of larvae	11	19	85	13	48	9
Total days immersed	10	2	3	5	½	2
Harrison stage at hatching	42–3	42–4	44–6	42–6	....	....
Total length, mm	13	13	13–5	13–5	15–8	18
Temperature, degrees C	21	21	15	21	21	21
Date of hatching	Oct.20	Oct.20	Oct.27	Oct.30	Nov.23	Dec. 9

If the nests were located in the dampest part of the area, the first heavy rain would enable all the larvae to hatch. Subsequent drying would be fatal to the entire population. The habit of placing the nests beneath heavy leaf litter and at a slight elevation usually prevents such premature hatching, since most of the eggs do not hatch before permanent flooding occurs. The completion of hatching is attributed to the action of unicellular glands on the head, but in addition water must be absorbed before hatching can occur. The softening of the envelopes plus the wriggling movements of the larvae permit its escape. Either the head or the tail may emerge first. Larvae with the gelatin capsules still fastened over their heads are common sights.

The embryo is able to emerge from the gelatin by the time it has reached Harrison stage 42. Noble found larvae able to

hatch in a slightly less developed condition, stage 38 approximately. Two-thirds of the larvae used in the same experiment, however, hatched at a later stage comparable to the above. Eggs kept at low temperatures until past their normal hatching time were able to emerge when as young as stage 40. This

TABLE II

GROWTH OF LARVAE FROM EGGS LAID IN THE LABORATORY

Eighty-one eggs were laid in the laboratory October 8. October 10 only 11 showed embryological development. These were placed in a fingerbowl containing tap water at room temperature, and daily observations made.

DATE	HARRISON STAGE	TOTAL LENGTH, MM.	REMARKS
October 10. . .	8–9	3 (D. of capsule)	11 living
October 11.. . .	21		11 living
October 12....	27	4 (D. of capsule)	11 living.
October 13	31		8 living.
October 14. . .	35		7 living.
October 16. ...	37	5 (D. of capsule)	1 photographed.
October 18......	39		
October 20. .. .	40		
October 23... ..	42	12 total length	6 living.
October 27. ...	43	12.5 total length	5 hatched Oct. 28–9.
November 3. ..	46	17 total length	pH of water 7.9.
November 10 ..	46 plus	18 total length	5 survivors.
November 17. .	46 plus	18 total length	4th digit appeared.

TABLE III

GROWTH OF LARVAE SECURED FROM FORT ANCIENT

DATE	HARRISON STAGE	TOTAL LENGTH, MM.	REMARKS
October 10	35	8	These larvae were freed from the egg capsules at the beginning of the experiment. Six larvae were used. The water was kept at room temperature. Its pH was 7.9.
October 12....	37	10.5	
October 14	40	13	
October 16..... .	41	15	
October 18	44	16	
October 20... ...	46	18	
October 23.	46 plus	18	
October 27. . ..	46 plus	19	
November 3.....	46 plus	20	

degree of development may be accomplished in 15 days or may require two months, depending on the temperature. In order to learn the lowest temperature at which eggs of *Ambystoma opacum* might hatch, five sets of ten eggs each were placed in water at 21° C., 7°, 5°, and 2° C. After 12 hours immersion ten larvae had emerged from the eggs kept at 21° C., five from the set at 12°, two from the set at 7°, two from the set

at 5° C., none from the set at 2° C. Eggs were often kept in water in the Frigidaire at a temperature of 2° to 3° C. without hatching. Thus 5° C. appears to be the minimum temperature at which the eggs will hatch. Eggs from which the outer capsules have been removed often fail to hatch even though placed in a favorable medium. The remaining capsule swells decidedly, becoming even larger than the original complete egg. The digestive action of the glands is reduced so that hatching is delayed.

THE EFFECT OF THE ENVIRONMENT ON GROWTH

It is apparent that the gelatin capsules are a vital necessity for the early life of the embryo. If the eggs are immersed in water before they are sufficiently developed to hatch, the ability to hatch appears lessened. However, embryos as little advanced as Harrison stage 35 thrive better without their capsules. Larvae of this stage are able to swim actively upon mechanical release. Larvae described in Table III were 18 mm. in length and were in stage 46 on October 20, ten days after having been freed from their capsules. Eggs from the same collection and kept in the same environment with capsules intact hatched October 20. These larvae had attained a total length of 13 mm. and were in Harrison stage 42–3. In another experiment liberated larvae measured 20 mm. the day that eggs from the same nest and kept in the same fingerbowl hatched at a total length of 17 mm. With all other factors remaining constant, larvae that have been freed from their capsules after having reached stage 35 show a more rapid development than those with capsules intact.

In view of these observations it seemed that rapidity of growth might also be dependent upon a number of factors such as temperature, ability to move about and the food available after hatching. A Frigidaire and a laboratory room offered uniform environments in which to conduct experiments necessary to show the effects of these different conditions, (Table IV). Eggs from the same nest were used. All larvae showed a similar degree of development, Harrison stage 40, at the beginning of the experiment. Three groups of animals were used in each location. All were kept in the dark. In Experiment A, eggs with capsules intact were placed on damp soil. In B, eggs with capsules intact were placed in water. In C, larvae freed from their capsules were placed in water. The experiment was

TABLE IV

EXPERIMENTS SHOWING THE EFFECTS OF ENVIRONMENTAL FACTORS ON GROWTH DURATION OF EXPERIMENT, 30 DAYS

ORIGINAL CONDITION OF LARVAE IN EXPERIMENTS A, B, AND C	EXPERIMENT A_1, FRIGIDAIRE TEMPERATURE 2° C.	EXPERIMENT A_2, LABORATORY TEMPERATURE 21° C.
Diameter of entire egg, 6 mm. Total length of larvae, 14–14.5 mm. Harrison stage 40. Fore limb bud undivided. No hind limb buds. Gills with few rami. Balancer present. Considerable yolk present.	10 eggs on water saturated soil. 6 survived, none hatched. Development: Total length, 14–14.5 mm. Harrison stage 40–41. Fore limb bud undivided. No hind limb buds. Gills with few rami. Balancer present. Little change in yolk content.	10 eggs on water saturated soil. 2 *survived in the egg.* 4 hatched on damp soil, perished. 4 perished in the egg. Development: Total length, 16 mm. Beyond Harrison stage 46. 4 digits on fore limb. Hind limb buds microscopic. Gill rami well developed. No balancers. More pigmented than A_1. Yolk practically exhausted.
HABITAT CONDITIONS, EXPERIMENT A Pint glass jars used as containers. Kept closed. Air practically saturated with water vapor. pH of soil in A_1, 5.6. pH of soil in A_2, 6.2.		
EXPERIMENT B, WATER ANALYSIS	EXPERIMENT B_1, FRIGIDAIRE	EXPERIMENT B_2, LABORATORY
Frigidaire / Laboratory pH................ 7.2 / 7.5 O_2, cc. per liter..... 9.00 / 5 82 Free CO_2, per liter.. 3.03 / 3.06 Fixed and half-bound CO_2 per liter...... 8.00 / 9 80	10 eggs entire, in 250 cc. tap water. 9 survived, none hatched. Development: Total length, 15 mm. Harrison stage 40–41. Fore limb buds undivided. No hind limb buds. Gill rami small. Balancers present. Possibly less yolk than in A_1.	5 eggs in 250 cc. tap water. 4 hatched within 24 hours. 3 larvae survived. 1 perished in the egg. Development: Total length, 18 mm. More advanced than Harrison stage 46. 4 digits on the fore limb. Hind limb buds microscopic. Gill rami well developed. No balancers. No yolk material remaining. Sise of head large in relation to body length, typical of starved larvae.

TABLE IV—Continued

EXPERIMENTS SHOWING THE EFFECTS OF ENVIRONMENTAL FACTORS ON GROWTH. DURATION OF EXPERIMENT, 30 DAYS

EXPERIMENT C, WATER ANALYSIS	EXPERIMENT C_1, FRIGIDAIRE TEMPERATURE 2° C.	EXPERIMENT C_2, LABORATORY TEMPERATURE 21° C.
Frigidaire Laboratory pH................. 6.9 7.05 O_2, cc. per liter..... 7.79 4.49 Free CO_2 per liter... 4.20 3.03 Fixed and half-bound CO_2 per liter...... 7.59 5.09	10 larvae freed from their capsules. Kept in 250 cc. tap water. 9 survived. Development: Almost identical to that in B_1. Total length, 15 mm. Harrison stage 40–41. Fore limb buds undivided. No hind limb buds. Gill rami small. Balancers present. Less yolk in gut than in B_1. Larvae lay inactively on the bottom most of the time.	10 larvae freed from their capsules. Kept in 3000 cc. tap water. 10 larvae survived. Development: Total length, 19–20 mm. Considerably more advanced than Harrison stage 46. 4 digits on fore limb. Hind limb bud microscopic. Gill rami well developed. No balancers. Gut filled with food. Larvae active. Their gills show some evidence of cannibalism. These larvae the most advanced of all experimentals.

conducted for 30 days, at the end of which time all larvae were examined and measurements taken. In general, it was found that none of the animals kept in the Frigidaire showed appreciable development. A slight advantage might be accredited to group C over the others, but even this is too small to be significant. Marked differences were seen in the animals kept in the laboratory. In Experiment A_2, 40% of the larvae hatched on the wet soil. At no time were the eggs covered with water. The two survivors show a significantly greater growth than those kept in the colder temperature but with other factors constant. In Experiment B_2, where the larvae hatched almost immediately, the effect of temperature on the ability to hatch is seen. Eggs kept at 2° C. did not hatch. Also since no food was present the extent of growth was limited, although freedom of movement was possible. In Experiment C_2, the most favorable situation regarding temperature, food and freedom of movement were found. A larger quantity of water was necessary to prevent mutilation of gills and appendages by other larvae. These larvae outstripped all others in their growth, reaching a total length of 20 mm., with the development of appendages and other organs in proportion. The difference in development shown by the two groups of animals in Experiment B is influenced by the fact that in B_2 the larvae hatched almost immediately. That this increased growth was not due to freedom of movement alone is shown in Experiment B_1 and C_1 by the failure of larvae freed from their capsules to grow appreciably more than those confined within the egg membranes, kept at the same temperature and in the same volume of water. While the results of this experiment show no new phenomena, quantitative effects of such known factors as freedom of movement, temperature, presence of water and food in their relation to growth are definitely shown.

At the time of writing, February 5, 1934, conditions in the field are severe in respect to the survival of the eggs and larvae of *Ambystoma opacum*. At two breeding sites under observation partial flooding occurred January 5 and 8, so that apparently all the eggs hatched. Within the month all the water either froze solidly or evaporated, causing the death of the larvae. Some pools are still dry, and here a good proportion of the eggs are yet viable. Their fate depends upon sufficiently heavy and permanent rains in the weeks that follow.

SUMMARY

1. *Ambystoma opacum* is an inhabitant of the swamp forests of southwestern Ohio.

2. Its nests are located on the margins of depressions which are pools approximately six months of the year.

3. The average number of eggs in 25 nests was 98.

4. The females brood the nests for at least a month. They were always found with their bodies resting upon the eggs.

5. The early growth is very similar to that of *Ambystoma maculatum* and may be compared with the Harrison stages figured for that species.

6. While a definite stage must be reached before hatching can occur, this growth may be accomplished in as short a time as 15 days. Older larvae hatch at a slightly less advanced condition than younger larvae that have grown more rapidly.

7. Eggs were not able to hatch at 2° C., but four out of twenty hatched at 5° C. The highest percent hatched at room temperature, 21° C.

8. Embryos of Harrison stage 35, 8 mm. in length, removed from their egg capsules and placed in water grow more rapidly than those that have been retained within the capsules.

9. A low temperature, 2° C., and dessication retard the growth of the larvae, while freedom of movement at a higher temperature, 21° C., and presence of food, Copepods and Ostracods, favor their growth.

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EXPLANATION OF PLATE

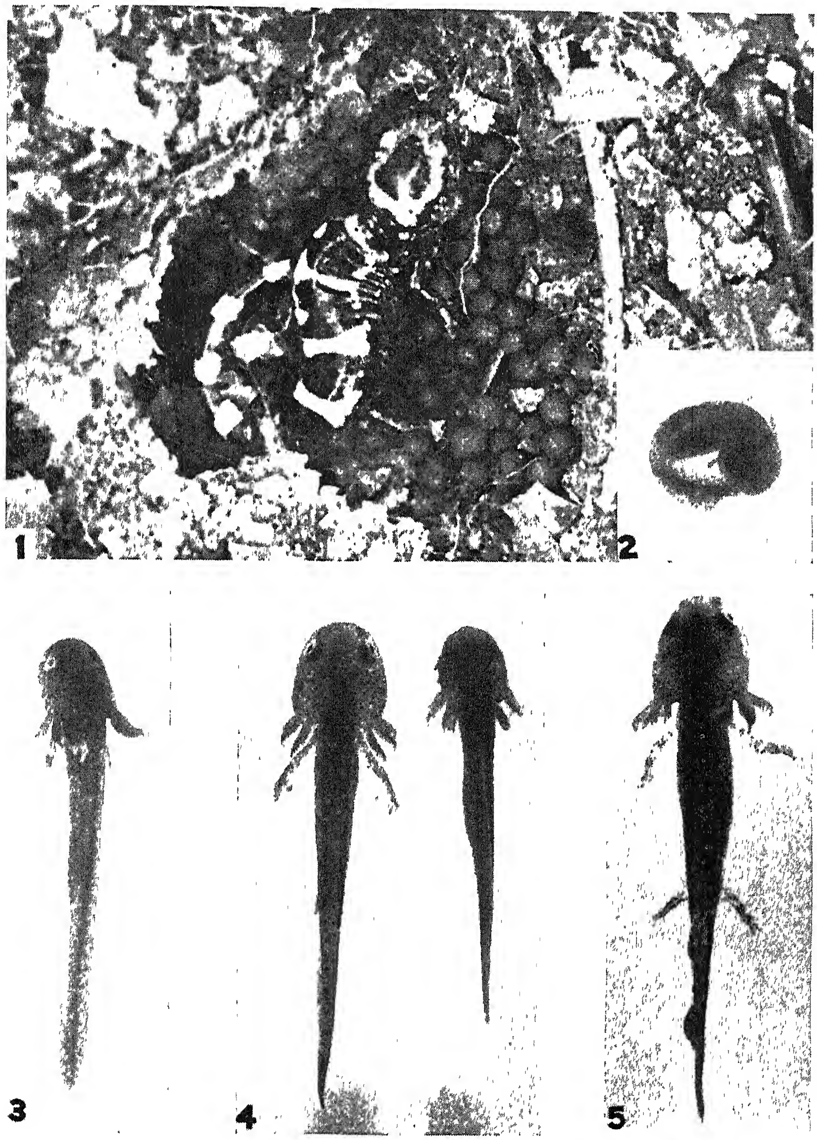
Fig. 1. Female *Ambystoma opacum* brooding her nest. Warren County, October 21, 1933.

Fig. 2. Egg with outer capsules removed. Harrison stage 40, 8 mm. total length. 5 × natural size.

Fig. 3. A typical hatching stage, Harrison stage 45. Total length, 18 mm. Larvae from Fort Ancient, December 15, 1933. 5 × natural size.

Fig. 4. Experimental animals showing the effect of temperature on growth. The larger animal was kept at 21° C., the smaller at 2° C. Both were taken from the same nest and freed from their capsules at the beginning of the experiment. The larger larvae shows four digits on the fore limb, rudimentary hind limbs, no balancer present, gill rami well developed. The smaller one has the fore limb bud undivided, no hind limb bud, balancer present, gill rami small. Similar food was available to both animals. All other larvae of the same sets are identical with these figured. 5 × natural size.

Fig. 5. A more advanced larvae, kept in an aquarium at room temperature for two months after hatching. 4 × natural size.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RESPONSE OF EUROPEAN CORN BORER[1] MOTHS TO COLORED LIGHTS

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Ohio Agricultural Experiment Station

INTRODUCTION

One of the most frequent questions and one of the most difficult to answer for those connected with corn borer research problems is that which concerns the phototactic responses of the adult or moth. The common impression that all insects are attracted to lights has led to the assumption that corn borer moths could be trapped in sufficient numbers to aid materially in the control of this pest. The fact that the moths are night fliers has further strengthened this assumption.

Because there was a general demand for definite information on this point, it was decided in 1926 to inaugurate investigations dealing with this phase of the problem. The data accumulated constitute the subject matter of the present discussion.

THE PROBLEM

Field and laboratory work was so outlined as to endeavor particularly *to determine the influence of lights of different colors on the behavior of the insects.*

MATERIALS AND EQUIPMENT

Description of Filters Used

Several filters, each 6½ inches square, were used in the colored light tests. These ray filters were manufactured by the Corning Glass Works, Corning, N. Y.

The code numbers for all of the filters have been changed since the work was started. Table I shows the wave-length, name, and number of the filters. It will be noted that the G34 and G24 used in these experiments have been subdivided, the visible transmission being determined by the position of the spectral cut-off. A brief description of each filter follows:

Pyrex.—This glass now known as Heat Resisting Clear Chemical Class No. 774 has medium ultra-violet transmission

[1] *Pyrausta nubilalis* Hubn.

and is highly transparent to visible radiation. The pyrex filter used in the tests transmitted light more freely than any other used; so the factor 1.0 was designated as the basal unit for calculating the transmission value of all the others.

Pale Blue Green.—This glass is now known as Light Shade Blue Green No. 428 and has the greatest ultra-violet transmission of any blue green glass available. It requires 9.61

TABLE I

SHOWING FILTER NUMBER WITH PRESENT NAME AND CODE NUMBER*

Old Number	New Number	Wave Length
G86B	Discontinued—now H. R.† Clear Chemical Glass, No. 774	295–780
G38H	Noviol Shade C, No. 338	480–720
G38L	Noviol Shade O, No. 306	380–720
G34	Covers a series of glasses as follows	525–780
	H. R. Red Shade Yellow, No. 348.	
	H. R. Lantern Shade, No. 349.	
	H. R. Yellow Shade, No. 351.	
G24	Covers a series of glasses as follows	600–780
	H. R. Signal Red, No 243.	
	H. R. Lantern Red, No. 244.	
	H. R. Traffic Red, No. 245.	
	H. R. Lighthouse Red, No. 246.	
G124J	Discontinued—Now H. A. Green, No. 492	320–780
G584J	Light Shade Blue Green, No. 428	300–660
G585L	Blue Purple Ultra, No. 585	290–485
G586A	Red Purple Ultra, No. 597	300–420
G55A	Signal Purple, No. 555	300–560

*The above information was furnished by D. L. Killigrew, Aviation and Optical Division of the Corning Glass Works. The wave length data were calculated from Sayre (5).

†H. R.—Heat Resisting.

times as much light as does pyrex for producing transmitted light of equal intensity; therefore, the ratio of intensity is 9.61 to 1.

Noviol O.—This filter is used to absorb ultra-violet, to eliminate haze and thus improve visibility both in visual and photographic work, and, in general, as a selective ray filter. The ratio of intensity is 1.14 to 1.

Noviol C.—This glass is characterized by the sharp transition between high transmission and strong absorption and is used to absorb ultra-violet. The ratio of intensity is 1.41 to 1.

Heat Resisting Yellow.—The old G34 filter used in these experiments covers a series of glasses as follows: H. R. Red

Shade Yellow No. 348, H. R. Lantern Shade No. 349, and H. R. Yellow No. 351. These are low expansion, heat resisting glasses with a sharp spectral cut-off ranging from red orange to lemon yellow, depending upon the position of the spectral cut-off. The ratio of intensity is 1.25 to 1.

Blue Purple Ultra.—This filter transmits .365 μ ultra-violet, .405 μ violet, .435 μ blue, and extreme red beyond .72 μ. The ratio of intensity is 3.07 to 1.

Heat Absorbing.—The blue green glass of this filter is effective for obstructing the infra-red, although it is not well adapted for absorbing the visible rays. The ratio of intensity is 2.18 to 1.

Signal Purple.—Both ends of the spectrum are transmitted. The ratio of intensity is 10.5, placing it slightly lower than Pale Blue Green.

Red.—The old G24 filter used in these experiments covers a series of glasses as follows: H. R. Signal Red No. 243, Lantern Red No. 244, H. R. Traffic Red No. 245, and H. R. Lighthouse Red No. 246. Inasmuch as the type of glass has nearly complete transparency for the longer wave-lengths, the visible transmission is determined mostly by the position of the spectral cut-off. The ratio of intensity is 2.45 to 1.

Red Purple Ultra.—This glass transmits .365 μ ultra-violet freely, .405 μ violet, and extreme red at about .72 μ. This filter has the lowest light intensity of any used in the tests, its ratio being 47.6 to 1.

Bulbs

Clear electric light bulbs of the strengths 10, 15, 25, 50, and 100 watts manufactured by the Mazda National Lamp Works (General Electric Co.) were employed in all of the tests. The 10-watt bulbs were 115V S14 Mazda B; the 15-watt bulbs were 115V S17 Mazda B; the 25- and 50-watt were 115V mill type P19; and the 100-watt were 115V PS25 Mazda C. Except in the 15-watt bulb, in which the filament was mounted straight, the filament in all the other bulbs used was mounted in the form of a helix. The advantage of using a lamp of the latter type is that the light is emitted in a straight line and not at an angle. The brilliance of a coiled filament is greater than that of a straight filament, due to the lesser projected area and the reflections from the inside of the coil.

When 50-watt and 10-watt bulbs were used together, it was

evident that the filaments would not be even; so the lights were mounted on adjustable holders to insure centering and compensating for intensity.

Assembled Apparatus

The apparatus used was in the shape of an oblong, rectangular box, 66″ long, 7″ high, and 18″ wide. (See Figure 1.) Ten filters were mounted in frames on one side. Screen wire

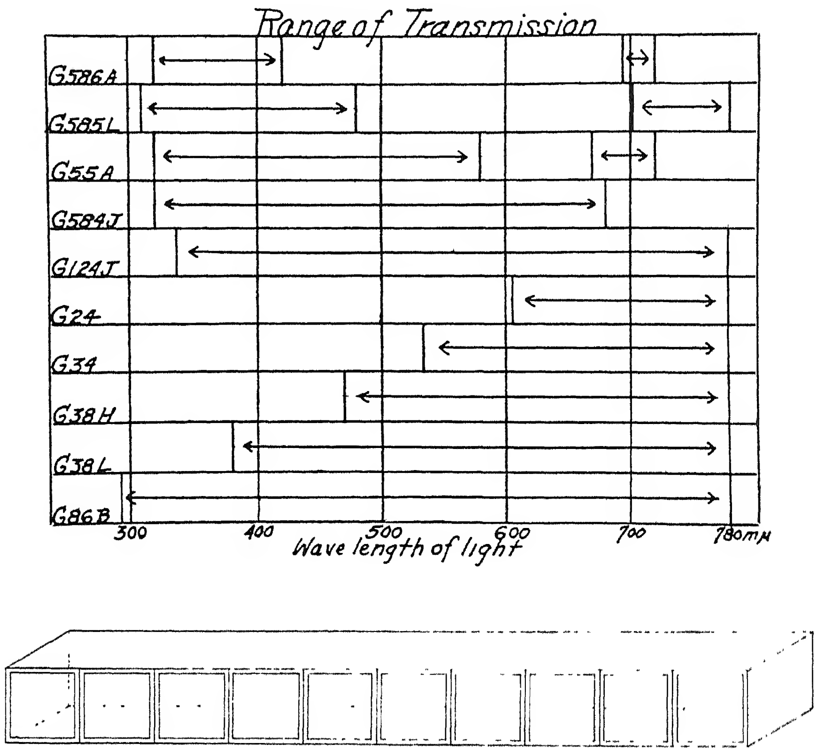

FIGURE 1

covered the top of the box, and a door in the wall opposite the filters permitted the introduction of the moths. The lights were arranged back of the filters on the outside of the test box and partitions separated them. The top was not covered.

The filters in this apparatus were arranged according to the way they are listed in Table II; that is, according to wave length. All of the calculations were made on the basis of 100. Thus Pyrex, the neutral glass, is placed in the center with the

filters having short wave-length on one side and those of longer wave-length than the pyrex on the other side, arranged in order of their wave-length. All lights were corrected for intensity.

TRANSMISSION DATA

The transmission data for the glass filters were obtained from the Bureau of Standards Technologic Papers by Coblentz and Emerson (1), Gibson and McNicholas (3), Gibson, Tyndall, and McNicholas (4), and Sayre (5). Gibson and McNicholas (3) present a chart and give instructions for converting these data which are for an equal energy spectrum. When the areas under the transmission curves were plotted on cross-

TABLE II

SHOWING RELATIVE DISTRIBUTION OF WAVE LENGTHS FOR CERTAIN FILTERS

Filter	+ Short	− Short	Median	+ Long	− Long
Red Purple Ultra	63	16	...	5	16
Pale Blue Green	22	27	27	22	...
Signal Purple	28	35	28	5	4
Blue Purple Ultra	36	32	...	...	32
Pyrex	20	20	20	20	20
Heat Absorbing	14	23	23	23	18
Noviol O	5	25	25	25	20
Noviol C	...	10	32	32	26
H. R. Yellow	...	...	27	41	32
Red	...	...	...	53	47

section paper and compared, the percentage of total transmission for each filter was obtained. These data were calculated for a spectrum extending from 290 mμ to 780 mμ. (Fig. 1.) Gibson and McNicholas (3) give 770mμ as the limit of visible spectrum.

The transmission curves for the filters are shown in Fig. 2 and are applicable only for filters of the thickness indicated in each case. The transmission of a specimen, as stated by Gibson, Tyndall, and McNicholas (4), is that fraction of radiant energy incident on the first surface which gets through the second surface. In a comparison of the transmissions of different glasses, due account must be taken of the variation in thickness. It was not necessary to have the filters photographed and their range of spectrum calculated because the graphs given by the Bureau of Standards paper and by Sayre are sufficiently accurate for the filters used in this discussion.

RELATIVE SPECTRAL DISTRIBUTION OF RADIANT ENERGY

Each screen varied considerably in the amount of light energy that is transmitted. The percentage of energy from the light transmitted by each filter was found by calculation.

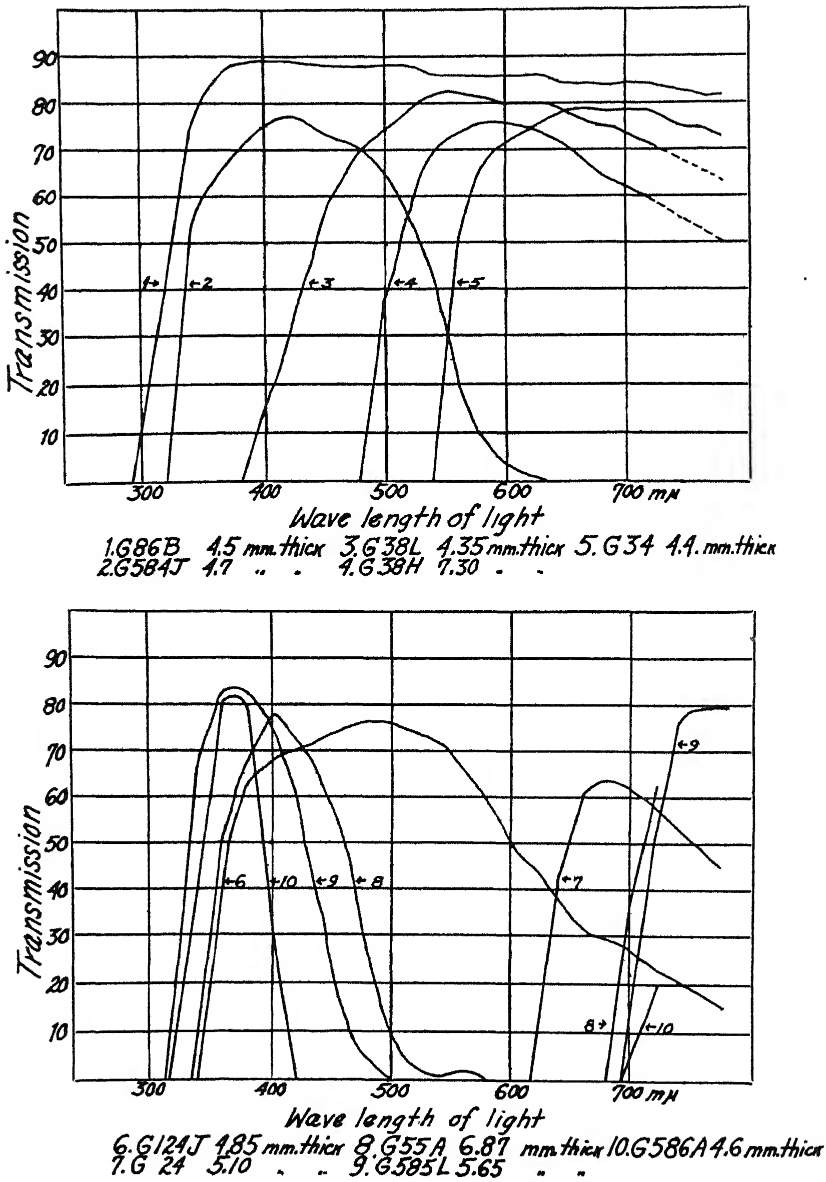

FIGURE 2

The data for the relative spectral distribution of radiant energy from 10-, 25-, and 50-watt Mazda B and 100-watt Mazda C bulbs were calculated from the curve given in General Electric bulletin Ld-114C. (7) (Figure 3.) The transmission value

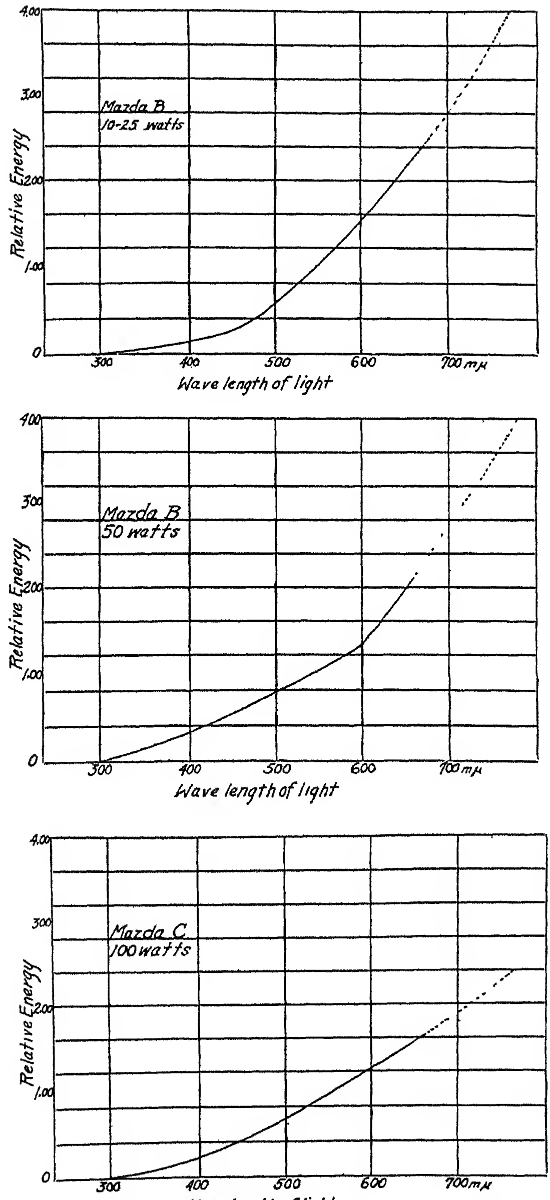

FIGURE 3

at each wave-length was multiplied by the values of relative spectral distribution of energy from the light. The areas under each curve were compared and reduced to percentages. The area of each curve thus measured is in proportion to the amount of light transmitted by a filter from bulbs of the same size placed at the same distance from the filter. These data are also applicable to Mazda lamps with inside frosted bulbs. In other words, the use of the frosted bulb does not introduce in the light output any factor that is not present in the clear glass bulb. The light is merely diffused and suffers a very small reduction in total quantity.

In a letter from General Electric Co., Harrison, N. J. (now Nela Park, Cleveland, Ohio), it was stated that "with the clear glass bulb it is apparent that the projected area of the light source; that is, the filament only, is small as compared to the projected area of the light source when an inside frosted bulb is used. In the latter case the entire bulb is considered as the source of light and hence its unit brilliancy is of a very much lower order than that encountered with the use of a clear bulb. In figures, the brilliancy of the inside frosted bulb is not over 2 per cent of that of a clear bulb."

SOURCE OF MOTHS USED IN THE WORK

All of the moths used in the laboratory tests were obtained from pupae which, as larvae, had spun up in corrugated paper strips. The paper strips containing the pupae were placed in large screen containers; the emerging moths were then collected from these and placed in smaller cages having a capacity of one hundred moths. The moths were kept for a period of 4 to 6 hours in a dark room of the same temperature and humidity as the one in which the light tests were conducted. The average temperature was 82° F. and the average humidity was 64 per cent. The boxes containing the moths were kept covered with damp cloths.

TECHNIQUE

Trial tests were conducted to determine the most satisfactory routine to be followed in introducing the moths into the light chamber. Lots of 100 moths each were placed in a compact wooden box with a screen wire cover. The sexes were kept separate. In some instances the moths were introduced at the end of the light chamber in which the short light waves

predominated; in other instances they were liberated in the end where the long light waves predominated; in still others they were released in the center of the box opposite the pyrex or neutral end.

The reactions of the moths were highly specific in that the insects introduced in the vicinity of the filters emitting light of short wave-lengths or in the center of the chamber opposite the neutral light exhibited a marked tendency to seek out the short wave-length lights. After a number of such trials it was finally decided that the most satisfactory point of introduction

TABLE III

SHOWING THE RESPONSE OF MALE EUROPEAN CORN BORER MOTHS TO COLORED LIGHTS

Replicates	Red Purple Ultra	Pale Blue Green	Signal Purple	Blue Purple Ultra	Pyrex	Heat Absorbing	Noviol O	Noviol C	H R. Yellow	Red	Total
1	25	18	7	3	8	2	1	1	1	0	65
2	14	10	10	5	6	1	0	2	2	0	51
3	13	17	4	4	4	1	0	0	0	0	43
4	22	15	12	4	2	1	0	0	0	0	56
5	23	12	7	5	3	1	0	0	0	1	52
6	13	8	11	2	4	3	4	0	0	1	46
7	8	12	18	3	3	0	0	0	0	0	44
8	11	8	10	5	5	2	2	2	2	0	45
9	4	9	5	3	6	2	1	1	1	0	32
10	30	14	12	6	5	2	1	0	0	3	73
11	19	14	14	5	7	3	2	1	1	1	67
12	7	7	10	9	8	4	0	0	0	0	45
Total	189	144	120	54	61	22	11	7	5	6	619
Mean	15.8	12.0	10.0	4.5	5.0	1.8	0.9	0.6	0.4	0.5	

was in the center of the cage opposite the Pyrex or neutral light. It is possible, however, that this procedure may have unduly influenced the number of insects going to Pyrex, since a study of Tables III and IV shows a slightly larger number of moths attracted to Pyrex than to the theoretically more attractive and immediately adjoining light, Blue Purple Ultra. Moreover, the difference in the number of moths selecting Pyrex and those selecting the adjoining, less attractive Heat Absorbing was greater than theoretically would have been expected.

The tests were replicated many times, and before each trial the entire apparatus was carefully checked in order that the

same adjustment obtained for all tests. The lights in the room, except those connected with the apparatus, were extinguished while each test was in progress.

At the outset, it was not known how much time should be allowed the moths to complete their response. After a number of trials it was found that if the insects were given 20 minutes in which to adjust themselves, little change in position occurred thereafter; hence this period was used as the interval allowed for response throughout the work.

TABLE IV

SHOWING THE RESPONSE OF FEMALE EUROPEAN CORN BORER MOTHS TO COLORED LIGHTS

Replicates	Red Purple Ultra	Pale Blue Green	Signal Purple	Blue Purple Ultra	Pyrex	Heat Absorbing	Noviol O	Noviol C	H. R. Yellow	Red	Total
1	17	22	6	4	6	6	0	0	0	0	61
2	12	11	8	7	6	2	1	0	1	0	48
3	22	11	9	7	6	1	1	1	0	0	58
4	22	16	8	3	4	0	0	0	1	1	55
5	21	17	8	3	6	0	0	0	0	0	55
6	16	11	7	5	4	2	0	0	0	0	45
7	7	14	9	5	5	2	1	3	0	0	46
8	10	12	6	4	4	1	0	0	1	0	38
9	11	11	10	7	8	3	1	2	0	0	53
10	11	9	7	6	7	2	0	0	0	1	43
11	16	12	10	6	13	1	2	2	0	1	63
12	6	11	5	6	4	2	1	0	0	2	37
Total	171	157	93	63	73	22	7	8	3	5	602
Mean	14.3	13.1	7.8	5 3	6.1	1 8	0.6	0.7	0 3	0.4	

After the moths had once selected a light chamber, they were not easily disturbed, even though at the conclusion of an experiment the colored lights were extinguished and the room lights turned on directly above the apparatus.

RECORDED RESPONSES OF MOTHS AND ANALYSIS THEREOF

A study of Tables III and IV reveals the fact that the moths respond to the colors in order of their descending wavelengths. Reference to Table II shows that Red Purple Ultra has 63% of its transmission in the short + end, 16% in short −, nothing transmitted in the median, 5% in long+, and 16% in long −. This is in accordance with the description of the

filter which states that it transmits .365 μ ultra-violet freely, .405 μ violet, and extreme red at about .72 μ. Pale Blue Green was very close to Red Purple Ultra in order of response, which may be explained by reason of Pale Blue Green transmitting farther into the ultra-violet than any other blue green glass available. There is a marked difference from these on down in the table. Signal Purple transmits 5% in long + as compared with Pale Blue Green 22%, but this is offset by a transmission in long −. Blue Purple Ultra has 36% transmission in short +, 32% in short −, and 32% in long −, which corresponds to its description as transmitting .365 μ ultra-violet, .405 μ violet, .435 μ blue, and extreme red beyond .72 μ. There is a sharp drop in response from Pyrex to Heat Absorbing. Noviol O, Noviol C, H. R. Yellow, and Red are about equal in order of response to the moths. Owing to the small numbers of moths responding, no explanation is offered for the fact that Red receives more moths than H. R. Yellow.

According to Fisher's (2) method of analysis of variance, there are significant differences in response of moths to wave length. In Tables II and III the means are given under each total. Using Fisher's table (where $t = \frac{(n_1 + 1) + (n_2 + 1)}{(n_1 + 1) + (n_2 + 1)}$) a difference of 2.805 for Table II must exist between the succeeding differences of the means of the response of male moths to wave-length before they are significant. Thus, for example, there is a difference of 3.8 between Red Purple Ultra and Pale Blue Green; hence, this difference is significant. In Table III the difference is 2.04, and for the combined male and female is 3.995.

CONCLUSIONS

When the filters were arranged in the apparatus in the ascending or descending order of wave-length, and the light transmitted through the filters was in all instances of uniform or comparable intensity, the moths responded in significantly greater numbers to the lights of short wave-length than to those of long wave-length; that is, the blue light of the series attracted more moths than did the red light on the opposite end of the series.

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Science Today

This is one of the better compendiums of the modern advance of science and scientific thinking. The general reader will find here the answers to questions about man, his heredity and his environment, his health, his complex relationships to his fellow men, and his place in the universe. The scientist as well as the layman will enjoy its stimulating discussions. It is not exactly easy reading, but it is most certainly thought-provoking. The authors of the various chapters are European scientists, experts in their respective fields. The following general subjects are discussed: heredity and human affairs, medicine, anthropology, physiology, psychology, sociology, theology, chemistry, physics, geology, astronomy, mathematics, logic, causality, and philosophy. The book is in many respects a modern liberal education, and is highly recommended.—L. H. S.

Science for a New World, planned and arranged by Sir J. Arthur Thompson; edited by J. G. Crowther. xxii + 398 pp. New York, Harper & Bros. 1934.

The Drama of the Universe

Would you have been thrilled to have stood by Galileo that night back in the early part of the seventeenth century when he gazed through his homemade telescope and discovered the satellites of Jupiter or the phases of Venus? Are you thrilled by groping out into space for millions and millions of miles only to find that you are still on the doorstep of the solar system while infinite space stretches away before you in the reaches of which spin objects and universes whose distances are no longer measured by miles but by the speed of light? Would you enjoy dashing back from the immensurably vast to the infinitesimally small dividing and subdividing matter into molecules, molecules into atoms, and atoms into electrons and protons? Do you take pleasure in analysing stars and nebulae into chemical compounds and elements, in dissolving the milky way into star clouds and universes, in speculating upon origins and ends? Would you shudder with the thought of seeing an asteroid bounce off the earth or another star crash into the sun, or with visualizing your descendantz a million million years from now slowly perishing on a ball of ice in the faint glow of a cooling sun or burned to a cinder under an overheated one?

If any or all of the above captures your fancy you will enjoy reading the new third edition of "The Universe Around Us." It is a bit overspeculative for the scientist but fascinating for the general reader; written in Jeans' inimitable dramatic style it offers much of value by way of information brought up to date, and many pleasant hours of relaxation.—D. F. Miller.

The Universe Around Us, by Sir James Jeans. Third edition. x + 380 pp. New York, The Macmillan Co. 1934.

FURTHER STUDIES OF THE GENUS EMPOASCA (HOMOPTERA, CICADELLIDAE)

PART III

SEVENTEEN NEW SPECIES OF EMPOASCA FROM THE UNITED STATES AND CANADA

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In 1931 a revision of the North American species of *Empoasca* was published by the U. S. Department of Agriculture as Technical Bulletin 231. Since that time nine new species were described by the senior author,[1] four new species were described by F. W. Poos[2] and nine were described by the senior author and J. S. Caldwell.[3] The present species are described from material collected by the senior author throughout the western United States in 1930 and from material in the University of Kansas Collection, a small collection from the Kansas Agricultural College, and small numbers of specimens sent to the authors by several workers in entomology.

Empoasca ponderosa n. sp.

Resembling *coccinea* in size and general appearance, but with distinct genitalia. Length, 3.5 mm.

Vertex one-third wider between eyes than length at middle, produced about one-half its length beyond anterior margins of the eyes.

Color.—Smoky green, tinged with yellow. Wings subhyaline, veins green.

Genitalia.—Female last ventral segment rather strongly roundedly produced. Male plates rather long, apices broad but upturned, appearing triangular in ventral view. Of the male genital pieces the oedagus is similar to *coccinea* and has a pair of long processes extending dorsally and caudally from the base of the oedagus proper. These are more slender than in *coccinea*. The dorsal spines are long, notched anteriorly at about half their length producing a long finger process wider at middle and suddenly constricted to a pointed tip. Spine directed anteriorly and ventrally.

Described from two male specimens, one from General Grant Park, California, August 12, 1930, and one from Pacific

[1] Ohio Jour. Sci. 32: 393–400, July, 1932.
[2] Proc. Ent. Soc. Wash. 35: 174–179, Nov., 1933.
[3] Ann Ent. Soc. Amer. 27: 604–609, Dec., 1934.

Grove, California, August 17, 1930, both collected by the senior author. Male holotype from Pacific Grove, California, in author's collection. Collected from Pine in these localities.

Empoasca convergens n. sp.

Resembling *fabae* in general appearance and coloration, slightly smaller and with distinct genitalia. Length, 3 mm.

Vertex about one-fourth wider between eyes than length at middle.

Color.—Pale green with variable markings, usually with a row of pale spots along anterior margin of pronotum.

Genitalia.—Male plates long and narrow, apices pointed. Of the male genital pieces, the lateral processes of the pygofers are rather long, stout, in ventral view, narrowed and pointed at apices with apical third rather strongly convergent. In lateral view they appear heavy, almost straight, with apex rather abruptly pointed. Dorsal spine consisting of two parts; the basal portion is broad and directed caudally and slightly ventrally. The apical portion is a long rounded, pointed spur which extends at right angles from the ventral apical portion of the basal part.

Described from a male and female specimen from Newaygo, Canada, April 22 and August 20, 1929, and three male and one female specimens from Toronto, Canada, September 1, 1929, tand a series of five male and one female specimens collected a Cedar Swamp, Ohio, by J. S. Caldwell, April 17, 1934. Male holotype and female allotype from Cedar Swamp, Ohio.

Empoasca dentata n. sp.

A small green species resembling *erigeron* in general appearance, but with distinct genitalia. Length, 3 mm.

Vertex bluntly produced more than one-half its length before anterior margins of eyes, almost twice as wide between eyes as length at middle.

Color.—Pale green to yellow, three dashes on basal portion of vertex and three spots on anterior margin of pronotum pale.

Genitalia.—Female last ventral segment produced and rounded. Male plates rather narrow, and covered with long hairs. Of the male genital pieces the lateral processes are long and narrow in ventral view with apices turned sharply outwardly and with rounded teeth-like processes on outer margins just before apices. In lateral view with apex slightly indented on upper margin. Dorsal spine broad, strongly curved anteriorly near middle, then narrowed to a pointed apex which is directed anteriorly and ventrally.

Described from a series of three male and two female specimens from Manhattan, Kansas, May 17, 1929, collected by D. A. Wilber, one male specimen from Douglas County, Kansas, at light trap, July 20, 1930, and one male from Cherokee County, Kansas, collected by Dr. R. H. Beamer. Male holotype and female allotype from Manhattan, Kansas.

Empoasca constricta n. sp.

Resembling *E. fabae* in general appearance, pale green with paler dashes and spots on head and pronotum. Length, 3 mm.

Vertex bluntly angularly produced, about one-fourth wider between eyes than length at middle.

Color.—Pale green washed with yellow, vertex with a median stripe and two oblique yellowish basal stripes. Pronotum with three pale spots on anterior margin. Wings greenish yellow, subhyaline.

Genitalia.—Female last ventral segment long, almost truncate. Male plates long and narrow. Of the male genital pieces the lateral processes are almost straight in lateral view with the upper margin concavely indented at apex, forming a finger process curved upwardly. In ventral view appearing constricted about one-fourth the distance from apex and with a pointed tip. Dorsal spine broad at base, rapidly narrowed then produced and strongly curved ventrally and anteriorly.

Described from a series of four male and four female specimens from Riley County, Kansas, collected in August and October; three male and two female specimens from Branford, Florida, July 31, 1930, and one male from Huachuca Mountains, Arizona, August 2, 1927, all collected by R. H. Beamer; also two male and two female specimens from Columbus, Ohio, September 15, 1898, and April 4, 1899, and one specimen from Gainesville, Florida, July 7, 1918 (C. J. Drake), all in Herbert Osborn collection.

Male holotype and female allotype from Columbus, Ohio; male and female paratypes from the above specified localities.

Empoasca diverta n. sp.

In general appearance and coloration resembling *pallidula* but with distinct genitalia. Length, 3 mm.

Vertex bluntly rounded, about one-fourth wider between eyes than length at middle.

Color.—Vertex brownish with pale markings. Pronotum and scutellum with a median pale area. Wings pale, veins white margined, with areas on corium broadly white.

Genitalia.—Last ventral segment with posterior margin roundly produced. Male plates broad at base, long with sharp points. Of the male genital pieces the lateral processes of the pygofers in ventral view are rather broad and directed inwardly and meet near the apices which are sharply curved outwardly and pointed. In lateral view the processes are slightly narrowed apically. Dorsal spine rather long, strongly curved anteriorly near its middle, narrowed and directed downwardly and ventrally.

Described from a series of four male and nine female specimens collected at S. Catalina Mountains, Arizona, April 25, 1926, by A. A. Nichol. The male is designated as the holotype.

Empoasca arta n. sp.

A small green species of the *fabae* type, but with more pointed head and distinct genitalia. Length, 3–3.5 mm.

Vertex bluntly pointed, one-fourth wider between eyes than length at middle. Pronotum almost twice as broad as median length.

Color.—Green washed with yellow, three basal pale lines on vertex; pronotum with three pale spots on anterior margin.

Genitalia.—Male long and slender. Of the male genital pieces the lateral processes of the pygofers are broad in ventral view, abruptly narrowed on outer margin near apex to form slender tips on inner margin. In lateral view with tips concavely excavated forming a finger process which is curved upwardly. Dorsal spine long and rather narrow, basal portion broad, strongly curved ventrally and anteriorly.

Described from one male specimen from Knight's Landing, California, collected August 22, 1930, by the senior author; one male specimen from Carson City, Nevada, August 9, 1929, and one male from Giant Forest, California, July 28, 1929, both collected by R. H. Beamer. The specimen from Knight's Landing is designated as the male holotype.

Empoasca occidentalis n. sp.

A banded species with angled head and with distinct genitalia. Length, 3–3.5 mm.

Vertex strongly angled, produced about one-half its length before anterior margins of eyes, about one-third wider between eyes than length at middle.

Color.—Pale green with bright green and smoky markings on vertex, pronotum and wings. Vertex usually with a pair of bright green markings on disc. Pronotum and scutellum smoky. A smoky green band across center of clavus and apex of wings. Anterior portion of clavus and area in front of anteapical cells pale, giving a banded appearance.

Genitalia.—Female last ventral segment with posterior margin produced, central fourth with a shallow square-shaped notch at center. Male plates short, appearing triangular. Of the male genital pieces the lateral processes in ventral view are strongly curved inwardly near tips. In lateral view these processes are almost straight. The dorsal spine is short and broad, slightly indented on inner margin, forming a sharp pointed process on inner ventral angle.

Described from a series of 48 specimens collected from Juniper at Twin Falls, Idaho, along the Snake River, in June, 1930; and one specimen from Donner Lake, California, August 6, 1930; two male and two female specimens from General Grant Park, August 12, 1930, all collected by the senior author. One male from Fish Lake, Utah, September 2, 1930; two male and three female specimens from Pingree Park, Colorado,

August 22, 1929, were collected by D. A. Wilber. Two male and two female specimens from Colfax County, New Mexico, August 21, 1927, collected by P. A. Readio and L. D. Anderson, and one male and three female specimens from Socorro County, New Mexico, August 18, 1927, collected by L. D. Anderson. Holotype male and allotype female from General Grant National Park, California.

Empoasca decora n. sp.

Resembling *aspersa* in size, coloration and general appearance. Length, 2.5–3 mm.

Vertex bluntly produced, about twice as wide between eyes as length at middle.

Color as in *aspersa*. Vertex, pronotum, and scutellum, pale green with irregular markings. Wings pale green to white, rather uniformly mottled with smoky areas. Veins pale to white.

Genitalia.—Female last ventral segment with posterior margin broadly roundedly produced. Male plates rather long, appearing pointed, set with heavy spines. Of the male genital pieces the styles are short, curved strongly inwardly and with tips divergent. Lateral process of pygofers rather heavy in ventral view. In lateral view appearing strongly curved dorsally on apical third and slightly narrowed. Dorsal spine rather short, broad tipped, and curved slightly anteriorly.

Described from a series of five male and five female specimens from Alpine, California, collected July 9, 1929; three male and three female specimens from Cedar City, Utah, collected August 19, 1926; one male specimen collected at Carson City, Nevada, August 9, 1929; and two male specimens from Alpine, California, collected July 9, 1929. All of the above specimens were collected by R. H. Beamer. A series of three male and four female specimens from Otera County, New Mexico, collected June 19, 1929, by Dr. R. H. Painter.

Holotype male and allotype female from New Mexico. Paratypes from localities mentioned above.

Empoasca venusta n. sp.

A pale yellow or green species without definite markings, resembling *fabae* in size and general appearance. Length, 3–3.5 mm.

Vertex about one-half wider between eyes than length at middle, bluntly rounded on anterior margin, not produced half its length before anterior margins of eyes.

Color.—Pale to bright green washed with yellow.

Genitalia.—Female last ventral segment produced on posterior margin. Male plates rather short and narrow at apex. Of the male genital pieces the styles are rather short and divergent at apex. Lateral processes of pygofers long in ventral view, with an abrupt bending outwardly, then inwardly, near apex with apices thin, slightly divergent

and curved outwardly. In lateral view appearing straight with pointed apices. The dorsal spines are short and broad with small pointed spur on the ventral anterior portion, entire spine slightly curved anteriorly.

Described from two male and two female specimens from Hocking County, Ohio, collected in September and October, 1933, by Dorothy M. Johnson. Male holotype and female allotype from Hocking County, Ohio.

Empoasca falca n. sp.

A blunt-headed species with slight banding. Length, 3.5 mm.

Vertex bluntly pointed, about one-third wider between eyes than length at middle, produced about one-half its length before anterior margins of eyes.

Color.—Vertex and pronotum brownish to yellow, wings greenish subhyaline with a faint smoky band across middle of clavus and another across apex of wings.

Genitalia.—Female last ventral segment with margin broadly produced. Male plates broad and rather short, appearing pointed at tips. Of the male genital pieces the oedagus is inflated on the apical half, the lateral processes of the pygofers rather short, in lateral view with apex narrowed and produced in a setaceous process. In ventral view the inner margins are concavely curved at the apex, forming finger processes on outer margin. Dorsal spines rather long, directed ventrally and anteriorly and gradually narrowed to a sharp point.

Described from two male and two female specimens, collected at Yosemite Park, California, August 10, 1930, by the senior author. Male holotype and female allotype in author's collection.

Empoasca plebeia n. sp.

Resembling *bifurcata* in general appearance, but with distinct genital characters. Length, 3 mm.

Vertex angularly produced, one-third wider between eyes than length at middle.

Color.—Green without definite markings. Wings greenish subhyaline.

Genitalia.—Male plates long and narrow with upturned tips. Of the male genital pieces the lateral processes are long and slender. In ventral view they form slender curved finger processes on outer margins curving inwardly. In lateral view these are constricted near apex and produced as slender tips. Oedagus long, extending more caudally than dorsally, and with a long finger process arising ventrally about half its length and curving caudally and dorsally. Dorsal spine broad and short, directed ventrally and slightly caudally, with a blunt apex.

Described from a series of fifty male and female specimens collected at Belle Glade, Florida, summer of 1929, by Hugh Clifton; a series of twenty-two specimens from Sanford, Florida,

taken at trap light, August 9, 1929, by C. O. Bare; a male specimen from Everglade, Florida, August 11, 1930, collected by Paul Oman; and a male specimen from Maricopa County, Arizona, August 7, 1927, collected by R. H. Beamer, and a series of male and female specimens in Ball collection from Port-au-Prince, Haiti.

Holotype male and allotype female are from Belle Glade, Florida.

Empoasca torqua n. sp.

Resembling *fabae* in general appearance, but with distinct genitalia. Length, 3 mm.

Vertex roundedly produced as in *fabae*, one-third wider between eyes than length at middle.

Color.—Green washed with yellow, vertex with white markings, three large spots on anterior margin of pronotum with central portion of scutellum white. Wings greenish, hyaline, unmarked.

Genitalia.—Male plate rather long and pointed, triangular. Of the male genital pieces the lateral processes of the pygofers are rather short, slender, and with short pointed apices. Styles short, curving outwardly. Dorsal spines broad at base, rapidly narrowed to rather long curved apical portion which is directed inwardly and curved upon itself.

Described from a series of four male specimens collected at Meridian, Mississippi, July 17, 1930, by R. H. Beamer; a series of six males collected in Champaign County, Ohio, in April, 1934, by J. S. Caldwell, and one male specimen collected at Vienna, Illinois, June 14, 1934, by H. H. Ross and the senior author. Male holotype and paratypes in author's collection. Paratype males in Kansas University Collection and Illinois Natural History Survey Collection.

Empoasca unca n. sp.

Size and general appearance of *fabae*, but with head more produced and genitalia distinct. Length 3–3.5 mm.

Vertex almost one-third wider between eyes than length at middle, bluntly angled, produced about one-third its length before anterior margin of eyes. Wings long and narrow.

Color.—Pale green, vertex, pronotum, and scutellum tinged with orange, a median basal spot on vertex, three spots on anterior margin of pronotum, and a pale median stripe on scutellum. Wing subhyaline, veins green.

Genitalia.—Male plates rather short, appearing triangular but with tips turned upward and curved. Of the male genital pieces the lateral processes of the pygofers are short and rather broad, in ventral view appearing notched on inner margin at apex, forming a sharply curved finger process pointing inwardly. In lateral view appearing slightly indented on upper margin at apex. Dorsal spine broad and short,

caudal margin strongly convexly rounded, ventral anterior corner produced into a short sharp spur-like process.

Described from one male specimen collected at Emery, Utah, August 16, 1929, and two males from Grand Canyon, Arizona, August 11, 1927, all collected by R. H. Beamer. Holotype male from Grand Canyon, Arizona. Male paratypes from Grand Canyon and Emery, Utah.

Empoasca ratio n. sp.

Resembling *birdii* in color and general appearance but with distinct genital characters. Length, 3.5 mm.

Vertex about one-fifth wider between eyes than length at middle. Wings long, considerably produced beyond abdomen.

Color quite variable. Some specimens are green with few or faint markings. In well marked specimens the ground color is pale green or yellowish, marked with dark brown on pronotum and scutellum, and basal half and apical third of wings. Usually three elongated pale spots on posterior half of vertex and three on anterior margin of pronotum.

Genitalia.—Female last ventral segment with posterior margin roundedly produced. Male plates triangular, appearing to have pointed tips. Of the male genital pieces the lateral processes of the pygofers are stout in ventral view, gradually tapering to pointed slightly divergent apices. In lateral view gradually curved upwardly and with pointed apex. Dorsal spine broad and rather short, directed ventrally and notched anteriorly near apex and somewhat ventrally, forming a ventral anterior process which is directed anteriorly and curved ventrally.

Described from a series of three male and four female specimens collected at Republic, Washington, August 6, 1931, by R. H. Beamer. Male holotype and female allotype in Kansas University Collection.

Empoasca dilitara n. sp.

A pale green species with orange yellow vertex and without definite color markings. Length, 2.5–3 mm.

Vertex one-fourth wider between eyes than length at middle, rounded in front, produced about one-third its length before anterior margins of eyes.

Color.—Vertex orange yellow, pronotum green, scutellum pale yellow, wings greenish yellow, subhyaline.

Genitalia.—Female last ventral segment roundingly produced. Male plates long and slender. Of the male genital pieces the styles are long and slender with tips divergent. The lateral processes of the pygofers are long and in ventral view straight on the inner margin. The outer margin curved outwardly to near tip where it rapidly narrows to a pointed apex. In lateral view the apex is constricted ventrally, forming a dorsal finger process. Oedagus in lateral view with posterior process extending dorsally at about the middle. Dorsal spine triangular, not curved, extending ventrally and with tip bending inward.

Described from a male and two female specimens collected in Eddy County, New Mexico, June 17, 1929, by Dr. R. H. Painter. The male is designated as the holotype and the female as the allotype.

Empoasca simplex n. sp.

Resembling *pergandei* in size and general appearance but with distinct genitalia. Length, 3.5 mm.

Vertex broadly rounded, scarcely produced before anterior margins of the eyes, about twice as wide between eyes as length at middle.

Color.—Vertex yellowish, pronotum, scutellum, and wings green tinged with yellow.

Genitalia.—Female last ventral segment with posterior margins produced, slightly emarginate at middle with indications of about three small teeth. Male plates long and narrow. Of the male genital pieces the lateral processes in ventral view are long, rather heavy, with tips slightly narrowed and convergent. In lateral view the processes are curved upward near the apices and are sharp pointed. The dorsal spine is rather heavy, somewhat strongly curved on anterior margin forming a rather short thick terminal process which is directed ventrally and slightly anteriorly.

Described from two male specimens from Shoshone Basin, Idaho, collected July 27, 1930, and one male from Blackfoot, Idaho, collected June 26, 1930, by the senior author; one male from Burns, Oregon, collected August 3, 1927, by R. H. Beamer and two specimens from Harper County, Kansas, June 22, 1929, collected by D. A. Wilber. Male holotype from Shoshone Basin, Idaho, in author's collection.

Empoasca similis n. sp.

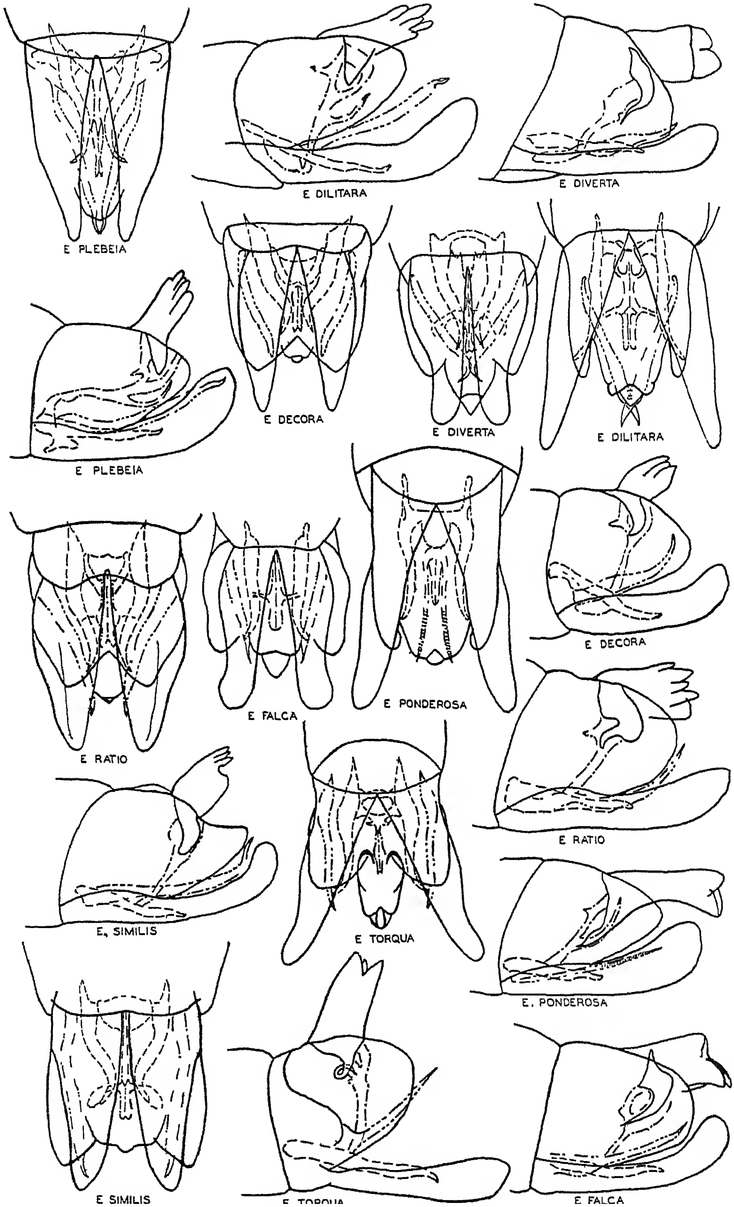
A small pale species with markings as in *aspersa*. Length, 2.5–3 mm.

Vertex bluntly rounded, almost twice as wide between eyes as length at middle.

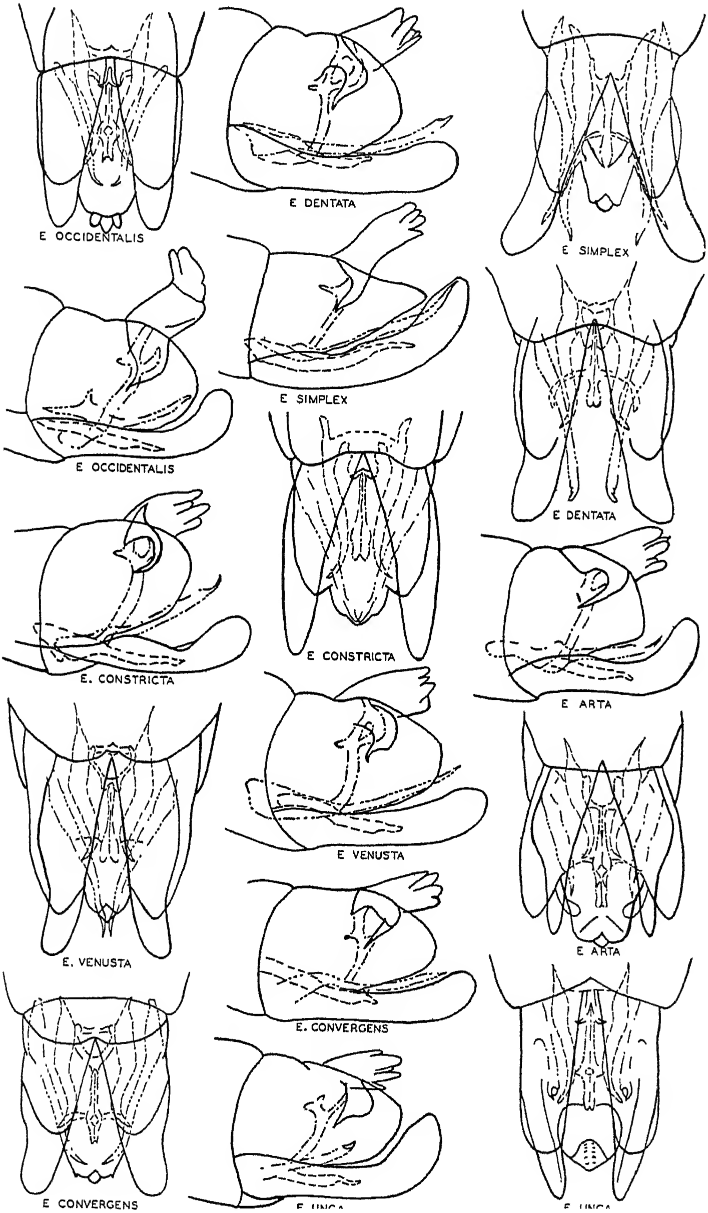
Color.—Milky white to pale green. Vertex, pronotum, and scutellum sparsely stippled with small dark dots. Wings mottled with dark pigment as in *aspersa*.

Genitalia.—Female last ventral segment broadly, roundedly produced. Male plates long, gradually tapered to sharp pointed apices and heavily set with long spines. Of the male genital pieces, the lateral processes of the pygofers in ventral view appear broad near apex where they are narrowed on inner margin and form slender finger processes which curve inwardly. In lateral view they curve abruptly dorsally near apex with apical tip curved slightly caudally. Dorsal spine short and broad, directed ventrally and curved slightly anteriorly.

Described from five male specimens from Carson City, Nevada, collected August 9, 1929, by R. H. Beamer. Male holotype in Kansas University collection.



Ventral and lateral views of male genitalia showing styles, lateral processes, dorsal spine and oedagus in normal position in the genital chambers.



Ventral and lateral views of male genitalia showing styles, lateral processes, dorsal spine and oedagus in normal position in the genital chambers.

THE EMBRYOLOGY OF THE WHITEFISH *COREGONUS CLUPEAFORMIS*, (MITCHILL)[1]

PART III.

THE SECOND HALF OF THE INCUBATION PERIOD

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As pointed out in the second paper of this series, it is during the first half of its normal incubation period that the embryo of *Coregonus* undergoes a differentiation of its primitive embryonic tissue into definitive organs. This differentiation applies to every organ system. It remains for the second half of the incubation period to develop these structures to such a state as to produce a self-supporting, highly co-ordinated individual organism at the time of hatching. Thus it is to be expected that the major changes which occur during this latter period involve chiefly such processes as growth, change in proportion of parts, and further differentiation of tissues.

Stage 608. O. S. U. Series.—(Incubation period, 102 days, 4 hours; 191 T. U. Total length of embryo, 10 mm.; 64 pairs of somites. Reconstruction drawings, Plate V., Figs. A. B. C.)

The embryo has continued its growth in size and length since the stage last described, and now has acquired a distinct fish-like appearance within the egg shell. It lies prominently above the constantly diminishing yolk sac, to which it is still broadly attached in the middle of the body. Anterior to this attachment, the head is flexed downward to conform to the curvature of the yolk. The body of the embryo, however, is sharply bent, usually in the form of a flat dextral coil on the yolk surface. The tail completes the circle and in many cases extends just past the head, beginning a second loop. This sharp torsion and flexion of the body make it impossible, as in Stage 400, to reconstruct more than the anterior portion of the embryo. The drawings of this stage are drawn at the same magnification as previous stages, and therefore permit comparative studies.

The brain is shown in Fig. C of Plate V, with the sense organs removed. The precocious development of the nervous system that has been apparent since the closure of the blastopore is possibly even more clearly shown here. The brain at this stage appears to be roughly twice its former size. This may be seen by comparing Stages 400 and 608 of Plate VI, where corresponding points on the two drawings are

[1]Parts I and II published in Ohio Journal of Science, Vol. XXXIV, Nos. 5 and 6, 1934.

connected by lines. In the latter stage is seen a great overarching of the brain, due to the expansion of the midbrain, which now overshadows all other parts in size. The optic lobes have enlarged and have grown upward, backward, and outward until laterally they greatly overhang the infundibulum. The infundibulum retains its formerly described position ventral to the midbrain, but whereas it formerly extended to well beneath the myelencephalon, its tip now barely reaches past the middle of the metencephalon. This apparent shift in position may be due to the great growth of the dorsal portions of the brain. The infundibulum itself has increased in length, and at its posterior tip is divided into a dorsal and ventral portion. The cerebellum is now a prominent transverse plate on the posterior face of the midbrain. It is confluent at its base with the midbrain in front and the walls of the medulla behind. It is flexed backward upon the latter, its backward movement being due to the expansion of the midbrain. The drawing, Fig. A, Plate V, through the median axis of the head shows that the cerebellum also penetrates the cavity of the optic lobes to a slight extent. The floor of the myelencephalon is arched through the center (Fig. B, Plate V). Laterally and immediately behind the cerebellum, its outer walls are scarcely raised above the floor. Behind this point, however, the walls rise rapidly into lateral ridges which bend toward the center and draw the fourth ventricle into a triangular cavity which rapidly diminishes to a minute canal which continues down the length of the nerve cord as the neurocoele. The forebrain at this stage bears a transverse suture which divides it into the telencephalon and diencephalon.

The anterior end of the notochord in Stage 608 (Figs. A and C) is somewhat in advance of its position in Stage 400. In the earlier stage, the notochord ended at a level somewhat behind the middle of the otic capsule. Now it extends slightly beyond the anterior margin of this capsule. This changed relationship probably is brought about through the growth and backward crowding of the brain and its sense organs, rather than any forward growth of the anterior end of the notochord, which is to be regarded as a relatively fixed point. The changes described above also have resulted in bringing the tip of the infundibulum and the anterior end of the notochord into close proximity, a relation which persists for the remainder of the embryo's development.

The prominent lateral branchial folds ventral to the otic capsule are in the same relative position as seen in Stage 400. However, the anterior end of the pharynx now extends much farther forward than previously described. Apparently a marked forward growth of the anterior end of the pharynx has occurred (see Plate VI). The upper and lower sheets of epithelium which line the primitive mouth cavity now run forward beneath the infundibulum from the level of the branchial folds to the level of the optic nerve. Here the epithelium is in contact with the superficial layer. Between the oral epithelium above and the floor of the brain lies a sheet of cartilage, which forms the base of the chondrocranium.

The three sense organs, namely, the nasal pit, the eye, and the otic vesicle, have undergone enlargement and marked development

since being last described (Fig. B, Stage 608). The nasal pit is deeper, larger and more terminal. The eye, by comparison, is considerably larger and somewhat rotated in position. The semicircular canals of the otic capsules have continued their development and now occupy a large portion of the space within the inner ear.

The roots of the olfactory, optic and trigeminus nerves were traceable in earlier stages and were plotted on the reconstruction drawings of them. Now they are larger and more clearly defined. In addition, it is possible to plot the placodes of cranial nerve III, and a placode composed of components of cranial nerves IX and X.

Stage 784. O. S. U. Series.—(Incubation period, 131 days, 12 hours; 324.5 T. U. Total length of embryo, 12 mm.; 64 pairs of somites. Reconstruction drawings, Figs A_1, B_1, C_1, of Plate V.)

Hatching occurred in this series of embryos at stage number 803, at a total of 355 thermal units of incubation. The present stage is therefore within a few days of hatching, and for purposes of this study can be regarded as equivalent to that stage. Mrs. Fish (1929) has described a specimen of the Whitefish at the time of hatching, and gives its total length as 12 mm., the same as recorded above for embryos at this stage. The actual length of the incubation period of the Whitefish probably depends upon a variety of both extrinsic and intrinsic factors which have yet to be studied experimentally for this species.

At the stage listed above, or just before hatching, the yolk sac is reduced to a vestige of its former size and it is more narrowly attached to the embryo than in earlier stages. The embryo itself is tightly coiled, with its tail passing around the head to describe one and one-half circles. The head and body have undergone changes in proportion which give it the appearance of the newly hatched fish. The eye is prominent and heavily pigmented with stellate chromatophores on a golden ground color. The pectoral fins are well developed and active in their "fluttering" movements, although they lack the definitive pterygiophores of the adult. The median fin fold is continuous from the dorsal to the ventral median line around the tail. The tail is active, and the movements of the embryo within its shell are conspicuous in living material.

Figures A_1, B_1 and C_1, of Plate V, represent reconstruction drawings of the head of such an embryo, drawn in the sagittal plane and from the surface view, with and without the sense organs. By comparison of the second figure, Fig. B_1, with the corresponding one of Stage 608, Plate V (also Plate VI), it is seen that in the interval between these two stages, there has been a marked prolongation of the anterior portion of the head into a snout, a change which has greatly modified the contour of the head and which has been accompanied by important changes in the relative positions of the neighboring parts. For instance, the telencephalon has grown in size and has become projected into the snout. It has carried with it the nasal pit, which was thereby shifted from a position subventral on the head to one that is terminal. The epiphysis has arisen as a conspicuous outgrowth from the roof of the diencephalon. The meso-diencephalic fold, which was so prominent in Stage 608, is less conspicuous laterally and at this stage is to be seen

only in the median line. Internally, Fig. A_1, the diencephalon is more clearly delimited from the adjacent portions of the brain. The velum transversum and the meso-diencephalic fold appear as distinct ingrowths from the dorsal wall in the median line and indicate the anterior and posterior limits of the roof of the diencephalon. Below, the recessus opticus and the tuberculum posterius serve as corresponding landmarks. The major change that has occurred in this region is the very marked thickening in the floor, lateral walls and roof of the infundibulum. These form the thalami and optic chiasma. The large fiber tracts within them are now clearly differentiated. This thickening of the infundibular walls has greatly reduced the size of the diocoele and compressed it laterally until it remains little more than a vertical slit. The dorsal, anterior, median wall of the infundibulum continues uninterruptedly into the greatly thickened floor of the midbrain which constitutes the crura cerebri. The mesencephalon has undergone a process of general enlargement, brought about by a thickening in its walls. The direction of growth has largely been lateral, in such a way that this portion of the brain now greatly overhangs the infundibulum and overarches the eyes. The thickened walls have developed at the expense of the mesocoele, compressing it laterally to reduce it to a relatively narrow ventricle. The metencephalon likewise has grown laterally to an extent equal to that of the mesencephalon, and appears externally as a transverse plate. Internally, however, the forward wall of the cerebellum is expanded to form two large lobe-shaped masses, the "valvuli cerebelli" (Herrick, 1924), typical of Teleosts. These valvuli project into the cavity of the midbrain, completely filling it in its posterior portion. Since the greater bulk of these valvuli is lateral to the midline, it is not shown on the drawing of the median section.

The nasal pit and the eye are completely differentiated as described above. The semi-circular canals can be seen as of typical adult structure. At their apices they bear ampullae lined with cilia whose beating motion can readily be seen in the newly hatched larva. It is possible to locate and follow to a limited extent the course of several cranial nerves, although no special staining methods were employed in the preparation of the sections of this stage. Cranial nerves I, II, and III appear essentially as described in previous stages. The trochlearis (NIV.) arises from the lateral wall of the cerebellum as a very small nerve, which cannot be traced in this material beyond its base. The large prootic ganglion which was interpreted in Stage 608 as being composed of cranial nerves V and VII remains as a single mass. A single ganglion with two principal roots which emerge in close proximity to the inner surface of the ear is interpreted as being composed of components of the cranial nerves IX and X. The writer has been unable to identify a separate auditory nerve. An unidentified ganglionic mass lies ventral to the ear.

From the foregoing descriptions it is very apparent that before *C. clupeaformis* hatches, it possesses well differentiated sense organs. They are developed far in advance of corresponding organs in *Serranus* and in certain other species.

Several significant changes have occurred in the bucco-pharyngeal

region. It will be recalled that in Stage 608, the foregut had begun its migration forward from its primitive position and at that stage it had progressed to the level of the optic nerve. Since that stage, with the development of the snout, this forward migration of the anterior end of the pharynx has continued, being carried forward with the anterior end of the head. The mouth opening has broken through terminally in its adult position. The bucco-pharyngeal cavity is lined with an epithelium which is laden with spherical, glandular taste buds, irregularly distributed. These resemble the taste buds of the Carp, as described by Edwards (1930), and probably are similar histogenetically. The sides of the pharynx are now perforated by five pairs of fully developed visceral clefts, separated by four pairs of visceral arches. In each arch can be traced the supporting strand of cartilage which bears a ridge of primary gill filament. The secondary, finger-like gill filaments do not form on these primary gill filaments until after hatching. This failure of the secondary gill filaments to develop before hatching may be widespread in the teleosts. The author (1931) has found a similar condition in *Micropterus dolomieu*, where the secondary filaments are first developed a few days after hatching. M. Plehn (1901) describes their differentiation in the perch apparently from larval material. An aortic arch extends through each gill arch at the base of the filament, and the circulation of blood through these vessels can be clearly observed in living material. The heart has considerably increased in size since stage 608, and the ventral aorta running forward from it enters the floor of the pharynx at the point of attachment of the first anterior gill arch. In the previous stage, it disappeared in the floor of the pharynx at a point correspondingly much more posterior.

The branchial cartilages are attached ventrally to the median hyoid cartilage and dorsally to the cartilage in the floor of the chondrocranium, both of which are developed at this stage. The base of the chondrocranium extends as a sheet beneath the brain for the entire length of the head forward from the anterior end of the notochord. The lower jaw is supported by Meckel's cartilage. To its posterior angle is attached the base of a rudimentary operculum. At the time of hatching, the operculum extends backward to cover the first two pairs of gill arches.

Posterior to the region shown in the reconstruction drawings, a relatively advanced state of differentiation has been attained by the various organs. The pectoral fins and median fin fold are described above. Body, tail, and pectoral fin movements are strong and vigorous for some time before hatching. The body wall muscles have well differentiated striated myofibrils. The pronephric ducts can be traced backward throughout the length of the body. They converge in the median line caudally and fuse into a single tube in the region of the anus. The blood vessels throughout the body are well differentiated. They are lined by a distinct endothelium and many are congested with blood cells. Such vessels as the internal carotid artery, jugular vein, hepatic portal vein, duct of Cuvier, the aortic trunks and dorsal aorta fall in this category. In living, newly hatched larva, the circulation of the blood in the main vessels can be clearly traced throughout the body.

DISCUSSION

It is clearly evident from the description of the later stages of embryonic development of the Whitefish that this species attains a high degree of differentiation in its tissues previous to hatching. As pointed out earlier in this paper, the anlagen of all of the major organ systems are clearly established during the first half of the greatly prolonged period of incubation. This condition leaves the embryo free to undergo extensive development and differentiation of these tissues for the remainder of its incubation period. Since the eggs are normally laid during the months of November and December, and do not hatch until the first few days of April, the period of incubation in point of time is comparatively long. In the present series, the incubation period lasted 134 days, at winter lake temperatures, slightly above freezing (1.5° C.). This is equivalent in thermal units to an incubation period of almost nine days at a temperature of 22° centigrade. In comparison with species whose eggs normally are developed under this higher temperature, in the late spring or in the laboratory, the Whitefish has a relatively long period of incubation. Such a period then may be regarded as permitting a high degree of differentiation to occur. These two factors of length of incubation period and the degree of differentiation attained by the embryo before hatching are undoubtedly closely co-ordinated.

The whitefish is typically teleostean in its embryology. The cleavage pattern of the egg and its mode of early development compares very closely with the classical descriptions of Wilson for *Serranus*, of Klein and Henneguy for the trout, of Kuntz and others for other teleosts. The process concerned with gastrulation and closure of the blastopore, and the subsequent organogenesis is in general consistent with such processes in other teleostean species, so well summarized by Brachet. However, a review of the three papers in this study will reveal several outstanding features in which *Coregonus* is distinct in its embryological development.

The astral systems are unusually conspicuous in the mitotic figures of the segmenting blastomeres in the early cleavage stages. The astral rays extend from the centrosphere in all directions to the periphery of the cell. Those rays which radiate from opposite centrosomes cross each other in the center

of the mitotic figure. They are not obscured in this region by the chromosomes, since the latter are extremely minute.

The anlagen of all the organ systems are definitely established in the first half of the incubation period. By the end of that period, Stage 400, O. S. U. Series, all the definitive parts of the adult brain are present as such. The eye is fully formed. The nasal and auditory pits have already sunken in from the surface ectoderm and have established a nervous connection with the brain. The heart and the chief definitive vessels contain blood cells and circulation has become established. The pharyngeal pouches are well developed, and the gut is closed over for most of its length and possesses a lumen. The liver is present. The notochord is fully vacuolated, and the adult number of paired muscle somites is present. Even the anlagen of the paired lateral fins are distinct. The embryo has attained two-thirds of its hatching length. In short, all the significant phases in the development of these various structures occur during the first half of the incubation period.

The whitefish serves admirably for the study of certain embryological features peculiar to teleosts. The process of the proliferation of erythrocytes from the intermediate cell mass in the median line of the embryo's body can be clearly traced. Again, the brain is precocious in its development. By the hatching stage, the relatively large size of the optic lobes, infundibulum, and the thalamus indicate an unusual degree of development in these regions.

The valvuli cerebelli, the gills, and fins are all well-known characters peculiar to teleosts. But it is of some interest to observe that these are among the last structures in the whitefish embryo to become differentiated, a fact which points to their specialized character. The swim bladder does not develop until after the hatching stage.

The whitefish undergoes a very radical shift in the position of its mouth during the latter half of the embryonic period. The primary ventral position of the forward end of the pharynx in close apposition to the infundibulum is unquestionably primitive and is suggestive of the ventral mouth of more primitive fishes. The migration forward of the anterior end of the pharynx to bring the mouth opening to the tip of the head is a conspicuous feature of whitefish development.

SUMMARY

This paper is the result of a preliminary study of the embryology of the whitefish, *C. clupeaformis*, of the Great Lakes, from fertilization to hatching. It is based upon a series of 803 egg stages. The eggs were taken at four hour intervals, day and night, throughout the period of incubation, a total of 134 days and 16 hours. In this series, those stages involving early cleavage, germ ring formation, the primitive streak, the formation and closure of the blastopore, and the differentiation of the primary germ layers are described in Paper I. Organogenesis from this point to hatching is discussed in Papers II and III, accompanied by reconstruction drawings. These trace the general development of the brain, sense organs, cranial nerves, notochord, muscle somites, pronephric tubules, the gut, branchial folds, and the heart.

The whitefish is in general typical of the teleosts in its major embryological processes. Its extended period of incubation makes it favorable embryological material, because of the possibility of obtaining closely graded series of embryonic stages. Outstanding features in the embryology of this series include (1) conspicuous astral systems in the segmenting blastomeres, (2) precocious differentiation of organs during the first half of the incubation period, (3) the marked forward migration of the mouth from a ventral to a terminal position, and (4) the relatively high degree of differentiation of the brain, gills and other organs just previous to hatching.

TABLE I

SYNOPSIS OF THE EMBRYOLOGY OF THE WHITEFISH, *Coregonus clupeaformis*

Stage No. O. S. U.	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
1	1	8	. . .	. . . .	8-celled blastodisc.
8	2	15	.	. .	Blastodisc 4 cells deep. Epidermic stratum forming. Early periblastic ridge.
16	3½	30	. .	. . .	Blastodisc 8-10 cells deep. Blastomeres reduced in size.
32	6	42	. . .		Formation of germ ring and subgerminal cavity. Syncytium of scattered nuclei in central periblast.
48	8	60	. .	. .	Germ ring is migrating around yolk. Blastoderm envelops upper one-third of yolk. Embryonic bud and primitive entoderm appear.

TABLE I—Continued

Stage No. O. S. U	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
64	11	82	. ..	....	Germ ring lies in equatorial plane. Embryonic shield forming. Ectodermal layer differentiated beneath epidermic stratum. Notochordal area outlined. First step in formation of the neurenteric streak.
80	14	93	....	...	Primary germ layers are established. Blastoderm encloses two-thirds of yolk.
96	16	97	2 0	....	Large yolk plug stage. Formation of primitive streak. Kupffer's vesicle appears. Lateral mesodermal plates distinct from surrounding layers. Neural keel forming in anterior end.
112	19	103	2.32	3 prs.	Optic primordia appear as solid cell masses. Narrow yolk plug stage.
128	22	108	2 96	11 prs.	Closure of blastopore. Three primary cerebral vesicles have developed. Solid neural keel. Notochord extends forward to level of midbrain. Kupffer's vesicle has reached its maximum development. Sensory plate appears laterally on the head.
144	24	112.5	... ...	14 prs.	Embryo extends one-half distance around curvature of the yolk, without torsion. Small cavities within optic sacs and forebrain. Auditory pit anlagen. Conspicuous but incomplete branchial folds. Incipient stages in formation of pericardial cavities.
160	27	115	3.5	21 prs.	Increased size of brain and optic vesicles. The latter are invaginated to form a two-layered optic cup, with choroid fissure and primordium of lens. Nasal pit anlagen appear. Single endocardial mass beneath pharynx, in midline. Incipient stage in formation of pronephric chamber and duct.
176	30	117.8	.....	24 prs.	Progressive development of features listed above.
192	32	120	.....	28 prs.	Midbrain divided into two distinct optic lobes, hindbrain into metenand myelencephalon. Fourth ventricle formed. Optic stalk Tail is distinctly raised above yolk, and is undercut by tail fold.
208	35	123	... ...	32 prs.	Forebrain differentiated into telenand diencephalon. Infundibulum in initial stages of development. Hyomandibular and first branchial pouches in contact with surface ectoderm. Small lumen in gut.

TABLE I—Continued

Stage No. O. S. U.	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
224	38	126	4 2	39 prs.	Nasal pit is elliptical, lined with columnar epithelium. Increased size of brain and eye is conspicuous Prominent 4th ventricle. Vacuolation of cells of notochord is evident throughout its length. First anterior branchial pouch has broken through to form an open gill cleft. The second branchial pouch is formed. Gut is closed throughout its length. Position of future anus appears at level of 36th–37th somites. Paired dorsal aortae appear. Heart progressively developed. Pronephric chamber possesses a distinct cavity. Its duct extends to anal region. Continuous fin fold around tail.
272	46	134	. ...	49 prs.	Liver appears, as ventral outgrowth from midgut, at level of sixth somite.
288	48	136 4		52 prs.	The 3rd and 4th branchial pouches appear. Myofibrils have formed in somites throughout middle of trunk. Embryonic coelom is conspicuous at this level.
304	51	139	.	56 prs.	Pectoral fins appear.
320	54	142	.	62 prs.	Notochord surrounded by hyaline sheath. The dorsal aorta is traceable into tail region. Caudal vein and subintestinal vein appear. Gut possesses distinct lumen throughout its length.
352	59	147	.	62 prs.	Pronephric chambers at level of 4th and 5th somites possess glomeruli in their walls, receiving branches from the dorsal aorta.
368	62	150	. ...	64 prs.	The complete hatching number of somites is attained with this stage. Cross-striations occur in myofibrils of anterior somites.
400	67	155	8	64 prs.	Embryo forms an almost complete circle on yolk. Brain lobes have become greatly expanded laterally. Columnar epithelium is well differentiated in gastric region of gut. The heart is looped in the form of a U-tube and is suspended by mesocardium. Vitelline veins are large and filled with erythrocytes. Auditory vesicle irregular in outline, with ampullae and semi-circular canals developing within. Pectoral fins definitely raised above surface of lateral somatopleure. The pre-auditory sensory placode is evident, lying on the side of the head, anterior to hyomandibular pouch.

TABLE I—Continued

Stage No. O. S. U	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
608	102	191	10	64 prs.	Embryo forms a complete circle on yolk, with tail extending past the head, beginning a second loop. It has a distinct fish-like appearance. Yolk sac diminishing in size. This stage is marked by a great enlargement of the brain lobes, and a shift in their relative position. The posterior tip of infundibulum is divided into a dorsal and ventral portion. The anterior end of the pharynx has migrated forward beneath the infundibulum to the level of the optic nerve. Semicircular canals of inner ear are distinct. Roots of cranial nerves I, II, III, V, VII, IX, and X are plotted on reconstruction drawings.
784	131	324 5	12	64 prs.	Embryo forms 1½ circles on yolk. Approximately hatching condition. Yolk sac reduced to a vestige of former size. Eye heavily pigmented with stellate chromatophores. Active movements of pectoral fins, tail and tail fin in living material Prolongation of head into a snout, with corresponding changes in forward portion of brain Fiber tracts are differentiated within the thalamus and optic chiasma. Valvuli cerebelli project into cavity of midbrain. Progressive development of sense organs and cranial nerve roots. Mouth cavity has broken through in its adult terminal position on the head. Taste buds line the mouth cavity. Four pairs of gill arches are open on sides of head, partly covered by operculum Primary gill filaments present. Meckel's cartilage and the base of the chondrocranium are differentiated. The principal difinitive blood vessels are traceable throughout the body.
803	134	355	12	64 prs.	Hatching stage.

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EXPLANATION OF PLATES

PLATE V

Reconstruction drawings of Stages 608 and 784, O. S. U. Series, anterior end of embryo.

Figs. A and A_1—Median sagittal sections of the head in Stages 608 and 784, respectively.

Figs. B and B_1—Lateral view of head, in Stages 608 and 784, respectively, showing sense organs.

Figs. C and C_1—Surface of brain, without sense organs, in Stages 608 and 784, respectively, showing bases of cranial nerves, branchial arches, etc.

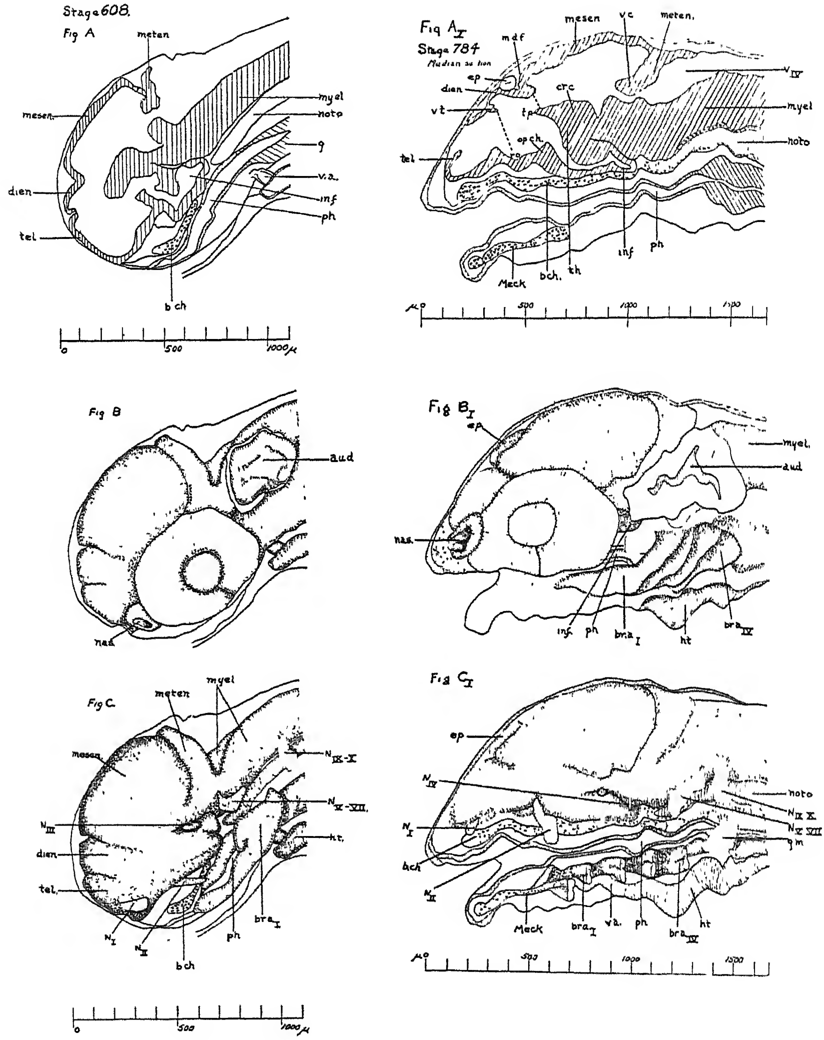
PLATE VI

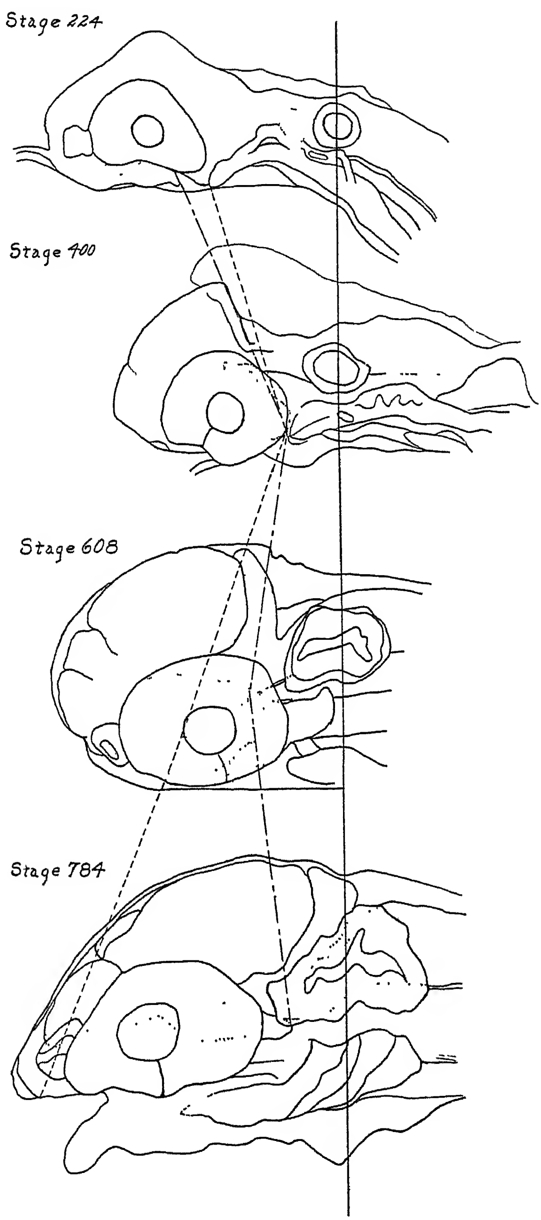
Reconstruction drawings of Stages 224, 400, 608, and 784, with the corresponding areas or points connected by lines, to show the changes in proportion and relationships during development. The base line is drawn through the center of the auditory vesicle.

(All figures are drawn at the same magnification.)

ABBREVIATIONS USED IN PLATE V

aud.—auditory vesicle.
br. a. I–IV—branchial arches, 1–4.
b. ch.—basis cranii.
cr. c.—crura cerebri (caudal peduncle).
dien.—diencephalon.
ep.—epiphysis.
g.—gut.
g. m.—ganglionic mass.
ht.—heart.
inf.—infundibulum.
m. d. f.—meso-diencephalic fold.
Meck.—Meckel's cartilage.
mesen.—mesencephalon.
meten.—metencephalon.
myel.—myelencephalon.
n. I, II, etc.—cranial nerves.
nas.—nasal pit.
noto.—notochord.
op. ch.—optic chiasma.
ph.—pharynx.
r. o.—recessus opticus.
t. p.—tuberculum posterius.
tel.—telencephalon.
th.—thalamus.
v. IV—fourth ventricle.
v. a.—ventral aorta.
v. c.—valvuli cerebelli.
v. t.—velum transversum.


Stage 608.
Fig A
meten
mesen
dien
tel
myel
noto
g
v.a.
inf
ph
b ch
0
500
1000 μ
Fig A
Stage 784
mesen
vc
meten.
mdf
ep
dien
crc
vt
tp
op ch.
tel
myel
noto
inf
ph
bch.
th
Meck
μ 0
500
1000
1500
Fig B
aud
nas
Fig B
ep
myel.
aud
nas.
inf
ph
bra I
ht
bra IV
Fig C.
myel
meten
mesen
N IX-X
N V-VII.
N III
dien
tel.
ht.
bra I
ph
N I
N II
bch
0
500
1000 μ
Fig C
ep
N IV
noto
N IX X
N V VII
N I
bch
N II
Meck
bra I
va.
ph
bra IV
ht
μ 0
500
1000
1500


Stage 224
Stage 400
Stage 608
Stage 784

THE ALIMENTARY CANAL OF CALASOMA SYCOPHANTA LINNEAUS

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In the following discussion are presented the results of investigations made upon the general morphology and histology of the digestive tract of the carabid beetle *Calasoma sycophanta* Linnaeus. These studies were made principally upon hibernating beetles.

This beautiful green metallic beetle is a native of Europe but has become abundant in New England since its introduction in 1906 to aid in the control of the gipsy moth (*Porthetria dispar* L.).

METHODS

The material was collected at various points in New England during the early summer of 1932 and 1933. The bulk of the material was kept alive in moist sphagnum moss until ready to make the dissections for laboratory study.

Beetles were taken from the hibernation container and dissected in normal saline solution for general anatomical studies. Where the tract was to be used for histological studies the specimen was first killed in a cyanide bottle and then dissected in Kahle's solution. The alcohols and Cedar Oil were used for dehydration and clearing. Difficulties were encountered in staining the sections. One stain might be fairly good for one region of the tract while it would not take at all in another region. Delafield's Haematoxylin and Eosin, as well as Heidenhain's Iron-Haematoxylin, gave only fair results in the posterior portion of the tract.

In making drawings, either a Camera Lucida or a projection machine was used for making the outlines and putting in as many of the cell walls and nuclei as stood out vividly. The minute details were put in free hand by the aid of a planescopic

[1]The writer is indebted to Dr. C. H. Kennedy for his helpful suggestions and criticisms of this work, also to Mr. C. W. Collins, and his entomological assistants at the Gipsy Moth Laboratory, for assistance in obtaining material for these studies.

microscope. All drawings might be classed as diagramatic but care was taken to present the material as much like the actual sections as possible.

GROSS ANATOMY OF THE DIGESTIVE TRACT

GENERAL ANATOMY

The alimentary canal in this carnivorous species is only slightly greater in length than the insect's body. The three primary divisions of the canal, based on embryonic origin, are distinct and their limits are well marked. The relation of these primary divisions (stomodaeum, mesenteron, and proctodaeum) to each other, and their component parts, is shown in Fig. 1, Plate I.

FORE-INTESTINE

The fore-intestine (stomodaeum) is little more than an elongated thin-walled sac, except for the gizzard which lies just anterior to the oesophageal valve. The fore-gut extends caudad into the mesothorax, comprising slightly less than one-third of the total length of the entire canal.

The pharynx is the slightly dilated portion of the fore-gut just posterior to the mouth, which connects the mouth with the oesophagus.

The oesophagus is nothing more than a simple tube of variable length connecting the pharynx with the crop. It lies in the posterior portion of the head and the anterior one-third of the prothorax. The only essential difference between this region and the two it connects is size, the oesophagus being the smallest. Apparently the pharynx and oesophagus have no function other than that of conduction.

The crop is present as a dilation of the tract immediately posterior to the oesophagus. It is a rather capacious thin-walled sac lying in the posterior two-thirds of the prothorax and the anterior portion of the mesothorax. In all the freshly killed specimens dissected the crop contained enough air to keep the walls distended although little food was present in the digestive tract of these hibernating individuals.

The gizzard is a thick-walled oval region lying just posterior to the crop and bounded posteriorly by the oesophageal valve. This portion of the tract lies within the mesothoracic segment. It is generally referred to as a grinding organ.

The oesophageal valve shows up externally as a distinct constriction of the tract immediately posterior to the gizzard, marking the division between the fore- and mid-intestines. This structure is located near the junction between the mesothoracic and metathoracic segments. It possibly functions in preventing regurgitation.

MID-INTESTINE

The mid-intestine (mesenteron) or stomach forms a conspicuous part of the alimentary canal, although comprising only about one-third the total length of the tract. It is bounded anteriorly by the oesophageal valve, located near the anterior part of the metathorax, and posteriorly by the pyloric valve and Malpighian tubules, located in the fourth

abdominal segment. There is a gradual reduction in the diameter of the mid-intestine from about the middle toward the posterior end at the pyloric valve. The stomach is a slightly tortuous tube, invested with numerous closely packed small villus-like enteric coeca, but the latter are much reduced on the posterior third. The coeca vary in size and shape as to whether beetles are in a hibernating or active condition. In the hibernating forms the crypts are small and finger-like in shape, while the crypts of actively feeding individuals are larger and bulbous at their bases. It is in the region of the stomach that most of the secretion (and absorption?) takes place.

HIND-INTESTINE

The hind-intestine (proctodaeum) comprises slightly more than one-third the total length of the tract and is differentiated into three regions.

The pyloric valve is located at the union of the mid-gut with the hind-gut, where the Malpighian tubules arise. This valve supposedly serves to close the posterior end of the stomach.

The Malpighian tubules are attached in the region of the pyloric valve and are four in number. All arise separately and at about equal distances apart around the tract. The bulk of the excretory tubules lies within the general region of the pyloric valve, but they extend as far anteriorly as the metathorax, and as far posteriorly as the sixth abdominal segment. The total length of the four tubules is approximately sixty centimeters. Many beetles were dissected and in no case were there loose ends of Malpighian tubules found. Evidently they unite distally but the four do not always make a common union, if ever. The diagram in Fig. 7, Plate II, shows a fusion of tubules found in one dissection, but no duplication of this in other individuals was found. Frequently two tubules are found which are superficially fused, but by careful dissection they can be separated.

The ileum, frequently called the small intestine, is not easily differentiated from the colon in gross dissection. It follows a rather irregular course but lies almost wholly within the fourth abdominal segment. Its function is obscure.

The colon links the distal end of the ileum with the proximal end of the rectum. It is a rather tortuous tube confined almost entirely to the fifth abdominal segment. At the posterior end, where it unites with the rectum, it is considerably reduced in size. Functionally the colon is a conduction tube.

The rectum is quite large and lies within the fifth and sixth abdominal segments. Six rectal pads are visible along the anterior portion of the rectum. The rectum connects the colon with the anus.

HISTOLOGY OF THE ALIMENTARY CANAL

FORE-INTESTINE

The histological structure of the fore-gut is quite uniform throughout its parts with the exception of the gizzard. An examination of the sections of the wall of the fore-gut shows the following tissues from

within outwards: (1) Intima of cuticula or chitin, (2) Epithelium of hypodermal cells, (3) Longitudinal muscles, (4) Circular muscles, and (5) "Peritoneal membrane" of connective tissue cells. In the gizzard there are, in addition to the above, spines which arise from the intima and project into the lumen.

The fore-intestine is lined throughout with a rather heavy layer of non-cellular cuticula or intima. It projects into the lumen of this portion of the tract in irregular wave-like folds. In the gizzard this layer is much heavier and thickened in such a manner that in cross-section it appears to be heavy teeth projecting into the lumen. There are large chitinous plumose spines which arise in the intima of the gizzard and project more or less caudad into the lumen. These ridges of heavy intima probably function in grinding up particles of food while the spines possibly tend to prevent the food from being forced anteriorly during the grinding process.

The epithelium which is composed of flattened irregular hypodermal cells forms the tissue just outside the intima in the oesophagus and crop. In the gizzard the epithelium is composed of rather regular cells.

In the oesophagus and crop there lies immediately outside the epithelium a series of bundles of longitudinal muscle tissue. There are usually six such bundles located at fairly regular intervals around the tract. There are associated with these bundles of longitudinal muscles small ducts which are probably trachae. In the region of the gizzard the longitudinal muscles form four large bundles, alternating with the chitinous projections of the intima, which are an important part of the crushing or grinding apparatus.

Surrounding the longitudinal muscle layer in the oesophagus and crop is a rather uniform layer, one or two strands in thickness, of circular muscle tissue. In the gizzard this layer of circular muscles is much thicker, being composed of several strands.

MI~~S~~T-INTESTINE (MID-INTESTINE)

The mid-intestine or stomach is markedly different from the fore- and hind-intestines in that there is no intima and the relative positions of the circular and longitudinal muscles are reversed.

Through histological study the following sequence in the positions of the tissues is found in the stomach from within outward: (1) Digestive epithelium of endoderm cells supported by a basement membrane, (2) Circular muscles, (3) Longitudinal muscles, and (4) Connective tissue, known as "peritoneal membrane."

There is no evidence of a peritrophic membrane.

The cells of the digestive epithelium are slightly columnar in structure but vary in size and shape. Many sections showed evidence of a striated border. The location of the regenerative tissue, or nidi cells, was not cleared up to the satisfaction of the writer. From the study of hibernating individuals it appears that probably the regenerative tissue is located within the crypts. In Fig. 5, Plate I, a diagram of a longitudinal section of a crypt is shown which has many very small cells near the tip. Rungius (12) has illustrated the structure of the

digestive epithelium of the crypts of *Dytiscus marginalis* L. It is similar to that of *Calasoma sycophanta* L. However, these digestive epithelial cells in the crypts are frequently arranged so that their apical ends point more toward the opening of the crypt into the stomach than those shown in Fig. 5, Plate I.

Whether the very delicate basement membrane is located next to the digestive layer just described, or whether it lies just outside the layer designated X in Figs. 4 and 5, Plate I, has not been determined. The structure of this X-layer has not been adequately investigated, but it stands out very vividly in sections stained with Iron-Haematoxylin. There are nuclei (labeled Y) in this layer which may be regenerative tissue, or possibly the whole layer X is regenerative in function.

The outer layer of the crypts is composed of rather large distinct cells. This Z-layer is liberally supplied with trachae. That would indicate that the X-layer may have a large component of tracheoles.

Surrounding the X-layer in the main part of the mid-gut there are two to three layers of circular muscles. This muscle tissue is rendered less conspicuous by the numerous crypts which protrude through the wall of the stomach.

Surrounding the circular muscles are isolated strands of longitudinal muscles.

HIND-INTESTINE

Histologically the hind-intestine presents from within outwards the following tissues: (1) Intima, (2) Epithelium of hypodermal cells resting on a basement membrane, (3) Circular muscles, (4) Longitudinal muscles, and (5) Connective tissue, or "peritoneum."

The Malpighian tubules are external structures of the hind-gut which arise in the region of the pyloric valve. These tubules are made up of numerous cells with large ovate nuclei. The cells have a striated border on their inner margin. Surrounding these cells is a thin layer of connective tissue.

The pyloric valve is marked externally by the origin of the Malpighian tubules. Histologically it is a folding over of the epithelium of the hind-gut into the lumen of the mid-gut. The length of the lips of the valve varies in different individuals. The hypodermal cells of the epithelium are columnar in structure as is true of the epithelial cells of the oesophageal valve. The valve is lined with an intima of chitin which extends as far forward as the point of union between the mid- and hind-intestines. There are numerous circular muscles just outside the epithelial layer, a slight distance posterior to the union, which may function in closing the valve.

The intima of the ileum, or anterior portion of the hind-gut, is quite heavy. The intima in this region has spines which may be easily overlooked due to the digestive products which accumulate around them. The epithelial layer in this region is also quite thick and makes six large folds which project into the lumen. Just outside the epithelium within these folds are strands of longitudinal muscles. The circular muscle layer is several strands in thickness just posterior to the valve.

Strands of the outer layer of longitudinal muscles appear as six bundles immediately outside the circular muscle layer. Connective tissue is evident in some sections of the ileum.

The colon has much the same histological structure as the ileum, but differs in that the intima and epithelial layer are thinner. The size of the colon is much reduced near the point of union with the rectum.

The rectum is much larger and has a much thinner wall than the other divisions of the hind-gut. There are six rectal pads located on the inner surface of the wall of the rectum near the anterior end which may be plainly distinguished due to the thickness of the rectal wall. These pads are composed of very large cells with ovoid nuclei. The pads lie between the intima and the very delicate epithelial layer. The layer of circular muscles which lies immediately outside the epithelial layer is but one to two muscle strands in thickness. The longitudinal muscles appear outside the circular muscles as six irregular bundles.

CONCLUSIONS

The alimentary canal of *Calasoma sycophanta* L. is slightly longer than the insect's body, a length which corresponds to its carnivorous habits. The three primary regions of the canal known as the stomodaeum, mesenteron, and proctodaeum are well defined, and show the following specializations:

Stomodaeum, or Fore-intestine.—Pharynx, oesophagus, crop, gizzard and oesophageal valve. It is ectodermal in origin and thus lined throughout with chitin.

Mesenteron, or Mid-intestine.—The whole region is known as stomach and is endodermal in origin, having no intima. There are evaginations of the digestive epithelium in the form of villus-like projections, termed crypts. These increase the area of the digestive epithelium enormously, and it is this layer which has to do with the secretion and absorption connected with digestion.

Proctodaeum, or Hind-intestine.—Pyloric valve, four Malpighian tubules, ileum, colon and rectum. There are six oval rectal pads on the anterior end of the rectum. The hind-gut is lined throughout with chitin, being ectodermal in origin.

The present study of the crypts has been far from sufficient enough to clear up their histology thoroughly. It is hoped that a more complete study of these structures will be possible.

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EXPLANATION OF PLATES

Plate I

Fig 1. A dorsal view of the alimentary canal.
Fig. 2. Cross-section through oesophagus.
Fig. 3. Cross-section through gizzard.
Fig. 4. Cross-section through crypt.
Fig. 5. Longitudinal section through crypt.

Plate II

Fig. 6. Longitudinal section through oesophageal valve.
Fig. 7. Diagram of fusion of Malpighian tubules. (See text.)
Fig. 8. Longitudinal section through pyloric valve.
Fig. 9. Cross-section through anterior portion of mid-intestine.

Plate III

Fig. 10. Sketch of crypts of a hibernating beetle.
Fig. 11. Sketch of crypts of a beetle in the active feeding condition. Drawn to same scale as Fig. 10.
Fig. 12. Cross-section of anterior ileum.
Fig. 13. Highly magnified portion of a cross-section of posterior rectum. (Muscle striations are much closer together than shown in any of these figures. There should be three muscle bands in a space the length of a muscle nucleus.)
Fig. 14. A portion of a cross-section through the region of the pyloric valve, showing entrance of Malpighian tubule.
Fig. 15. Cross-section of colon.
Fig. 16. Cross-section through a rectal pad.
Fig. 17. Cross-section of Malpighian tubule near origin.
Fig. 18. Cross-section through anterior rectum, showing rectal pads.

KEY TO ABBREVIATIONS

An. Gl.—Anal gland.
An. Gl. Res.—Anal gland reservoir.
C. Mus.—Circular muscle.
Co.—Colon.
Cr.—Crypt.
D. Epi.—Digestive epithelium.
Epi.—Epithelium.
Giz.—Gizzard.
Il.—Ileum.
Int.—Intima.
L. Mus.—Longitudinal muscle.
Lu.—Lumen.
M. T.—Malpighian tubule.
M. I.—Mid-intestine.
Oes.—Oesophagus.
Oes. V.—Oesophageal valve.
Ph.—Pharynx.
Rec.—Rectum.
Rec. Pad—Rectal pad.
Sp.—Spine.
Tr.—Trachea.
X—Layer which stains very dark with iron-haematoxylin.
Y—Possibly nucleus associated with regenerative tissue.
Z—Layer of rather large cells with distinct nuclei. Not fat cells.

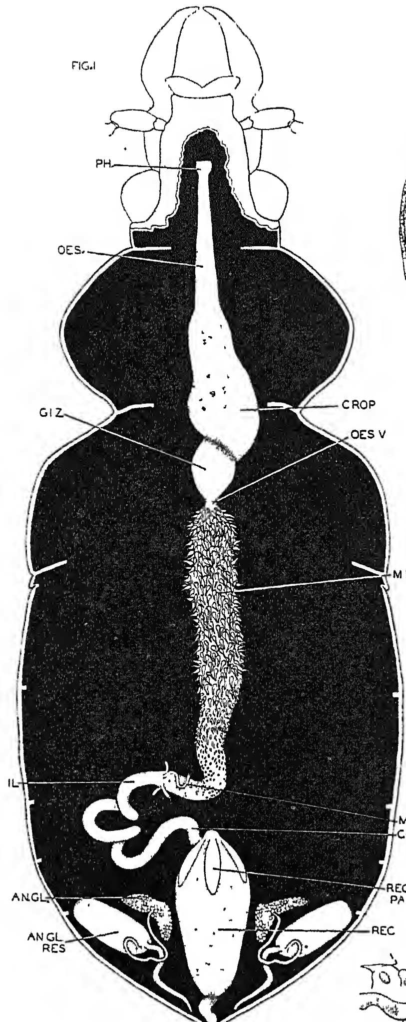


FIG.I
PH.
OES.
GIZ
CROP
OES V
MI
IL
MT
CO
REC PAD
ANGL.
ANGL. RES
REC

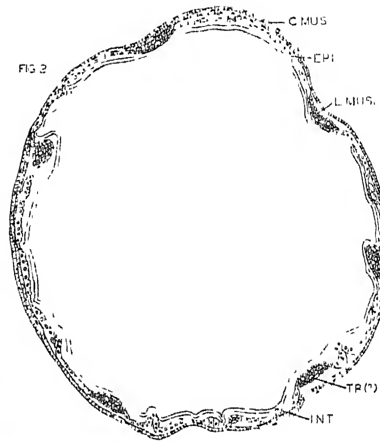


FIG 2
C MUS
EPI
L MUS.
TR (?)
INT

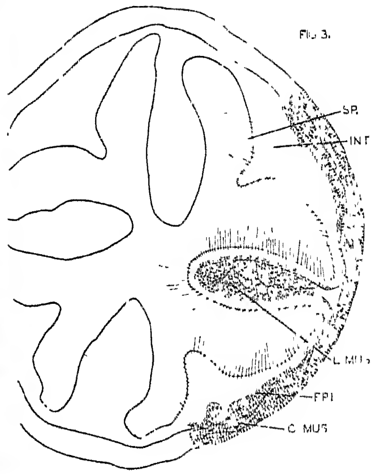
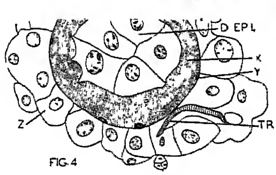
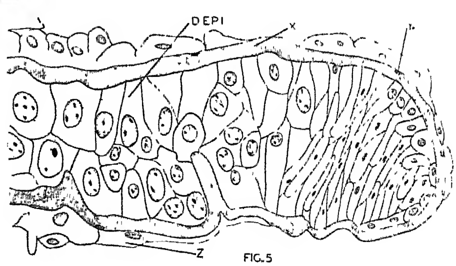


FIG 3.
SP.
INT
L MUS
EPI
C MUS


D EPI
X
Y
Z
TR
FIG 4


D EPI
X
Y
Z
FIG.5

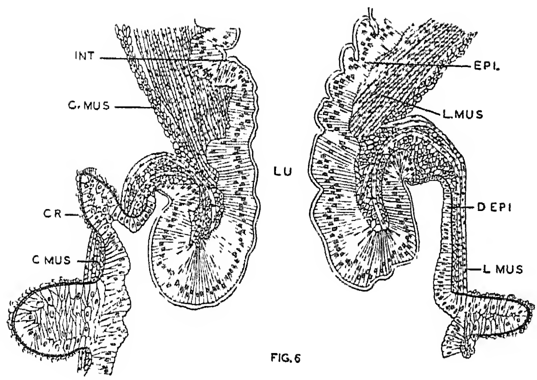


FIG. 6

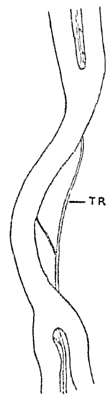


FIG 7

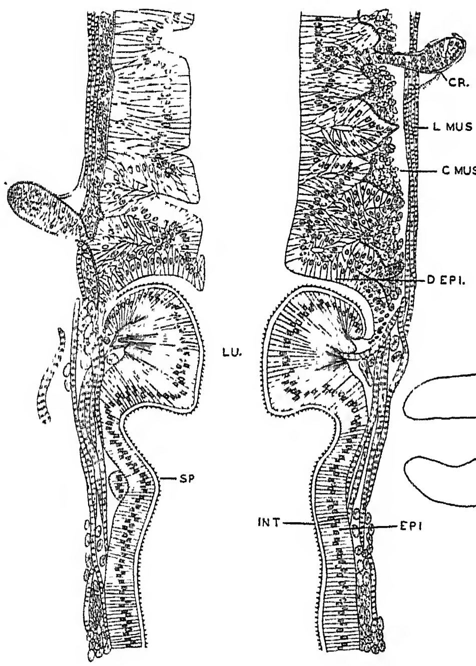


FIG 8

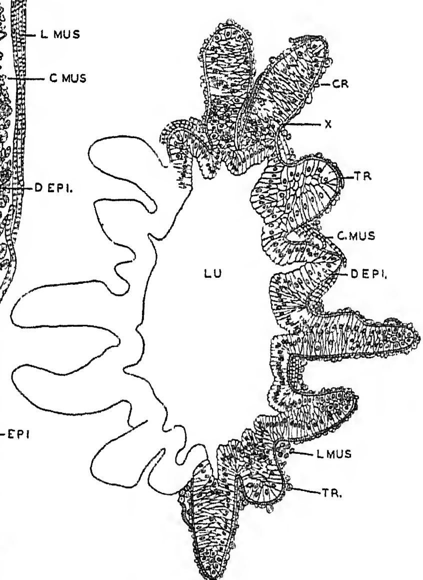


FIG 9

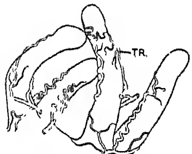


FIG 10

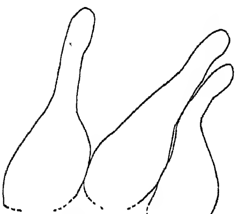


FIG 11

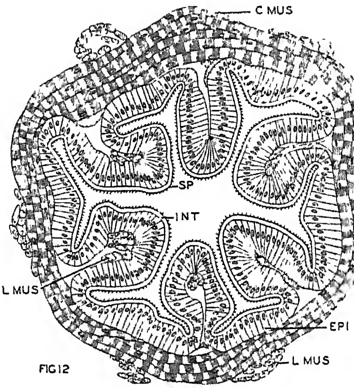


FIG 12

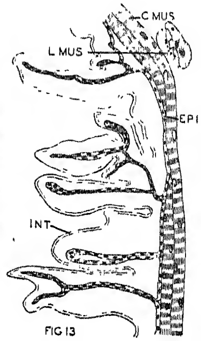


FIG 13

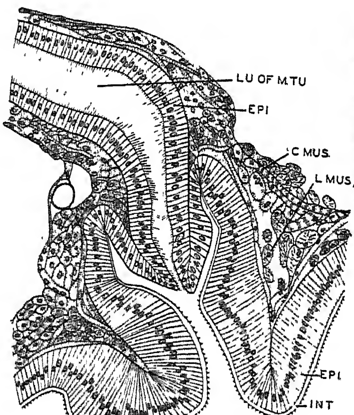


FIG 14

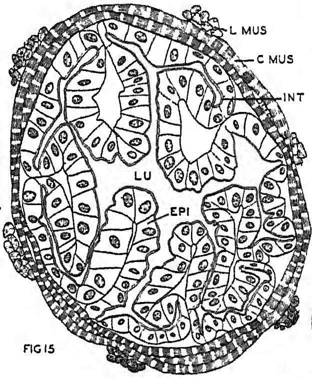


FIG 15

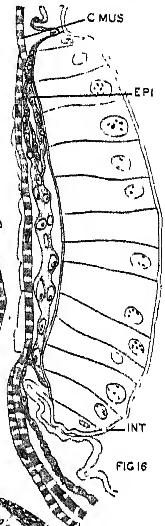


FIG 16

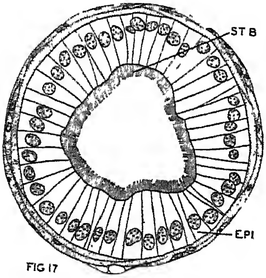


FIG 17

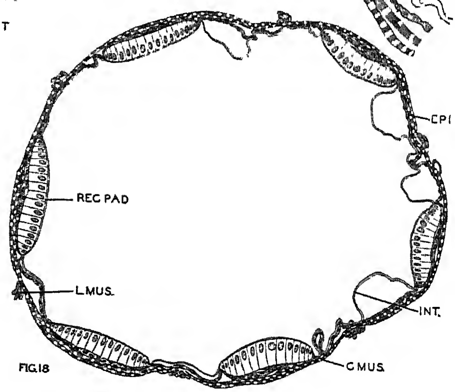


FIG.18

BOOK NOTICES

Man and His Biological World.

This is the second part of a two-volume introductory science course, the first part of which was reviewed in the September 1934 number of this journal. The book is written in easy conversational style, and brings out in a very interesting way the basic facts of biology. The attempt to make the book interesting has, however, been somewhat overdone, resulting in a lowering of the level of prospective students. As it stands, the book should be excellent for courses in high school biology, but probably not for college students, who should by college level be ready for more advanced material than is presented in this text.—L. H. S.

Introductory Course for Science in Colleges, II, Man and the Nature of his Biological World, by F. C. Jean, E. C. Harrah, F. L. Herman and S. R. Powers. x + 589 pp. Boston, Ginn & Co., 1934.

Health and Disease

This monumental volume is written to give to medical students, clinicians and practicing physicians a fundamental understanding of the principles of physiology which underlie the workings of the human body in health and disease. It is an inclusive and all-embracing volume, covering in its nearly 1,200 pages the methods of physiology, the principles involved, and a wealth of detailed information, with appropriate citations to the literature. Inevitably some subjects are sketchily handled, but on the whole the work is a real contribution to medical physiology.—L. H. S.

Physiology in Health and Disease, by C. J. Wiggers, M. D. xxvii+1156 pp. Philadelphia, Lea and Febiger, 1934.

A Co-operative Discussion of Psychological Thought

A group of specialists have brought together, under the editorship of Dr. F. A. Moss, a fine discussion of modern comparative psychology. Beginning with the historical background of the subject, the chapters proceed through "instinctive" functions, incentives and drives, effects of hormones, functions of receptors, the problems of discrimination and learning, the measurement and implications of individual differences, social concepts, and special abilities. The authors have done a fine piece of team-work, and have largely overcome the usual objections to a co-operative venture in writing.—L. H. S.

Comparative Psychology, by twelve psychologists, edited by F. A. Moss. xiii+529 pp. New York, Prentice-Hall, 1934.

What is Truth?

This is one of the most stimulating books it has been the good fortune of this reviewer to read in a long time. Pilate's age-old question is subjected to a searching analysis, resulting, of course, in the conclusion that the question itself is really devoid of meaning. The steps in the process of reaching this conclusion are, however, beautifully laid out. The book is replete with sentences and paragraphs that the reader could wish to frame and keep ever before him. Many of them will remain engraved on his memory for all time to come. To all searchers after truth this book is recommended as a bright light on a dim road.—L. H. S.

The search for Truth, by Eric Temple Bell. x+279 pp. Baltimore, The Williams and Wilkins Co., 1934.

Is the World a Soulless Mechanism?

"The Great Design" presents a brilliant symposium of all the sciences written by fourteen eminent scientists who have been asked "to state in outline how the world seems to them, first as scientists and then as men." Every subject, from stars to the green leaf, has been carefully and painstakingly developed and the result is a broad survey of science which is understandable to the layman and acceptable to the most exacting of scientists.

The only fault one can find with the book is the "purpose" for which it was written. Sir J. Arthur Thomson expresses it thus: " we are writing primarily for those who have not this assurance (that 'God's in His heaven, all's right with the world'), yet may be helped toward it by thinking quietly over the world which Science discovered, and by enjoying it, too."

Many of the writers are extremely scientific in the analyses of their particular fields, ignoring the whole matter of design in nature. Then they awaken to the fact (in the last paragraph of their chapter) that they must "present evidence that might seem to point to Mind or Intelligence behind nature," and they fulfill their "purpose" by quoting a poem, or an excerpt from the Bible.

The book gives intellectual satisfaction to those who are interested only in the philosophical implications of science, and scientific satisfaction to those who accept only the facts and accuracies of science and not metaphysics. Driesch, Metcalf, MacBride and the others seem to have combined the scientific and philosophical fields to their own satisfaction, but—is it Science?—H. S. HYMAN.

The Great Design, edited by Frances Mason. 324 pp. New York, The Macmillan Company, 1934.

Bibliography of Nature Study

For the use of teachers and others interested in nature study Professor Vinal has collected a bibliography of nearly two thousand titles together with their sizes, pages, publishers and prices. A loose attempt at classification of the titles has been attempted and some are indicated as especially suited for children. The list is composed entirely of titles in book form such as would appear in publishers catalogues and omits journal or magazine articles. In other words it is a book list. It might be of particular use in establishing a nature study library.

—D. F. M.

Nature Education—A Selected Bibliography, by W. G. Vinal. School of Education, Western Reserve University, Cleveland, No. 39; 82 pp. 1935. Unbound, mimeographed. Price, 75 cents.

Minerals

This handy book is divided into three parts; first, "About Minerals in General," in which in 126 pages are given the general phenomena and the various ways of handling them. The second part confines itself to the "Description of Minerals," where, in 124 pages, are described some 180 fairly common or important minerals. The third, "Description of Rocks," devotes 11 pages to handling some two dozen common rock types. Appendix I has tables for identification of minerals (33 pages). Appendix II is a Pronouncing Vocabulary, six pages with a good index at the end. For the numerous amateur mineral-collectors this is a good beginning handbook. For those who desire to know the more abundant minerals it should prove a great boon. It is not technical as are the orthodox books on minerals. On the other hand, it is not a great departure from the classic texts. For the casual student of minerals, it should prove very useful. Mr. English has produced a book which eloquently speaks for itself and which should find many users.—WILLARD BERRY.

Getting Acquainted with Minerals, by George L English. xi+324 pp., 258 illustrations. Rochester, N. Y., Mineralogical Publishing Co., 1934.

THE OHIO JOURNAL OF SCIENCE

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THE OHIO RIVER FLOOD OF MARCH, 1933[1]

WALLACE T. BUCKLEY

In March, 1933, the Ohio River Valley experienced the most severe flood since the disastrous overflow of 1913. From Point Pleasant, West Virginia, to Shawneetown, Illinois, the crest stage of this most recent flood was the highest since that of 1913, while at Cincinnati the river reached the fifth highest stage in its recorded history. Upstream from Point Pleasant the flood of March, 1933, was less severe than that of 1927. Attendant upon the overflow was the usual destruction of life and property as well as disruption of both land and water traffic along the Ohio Valley.

The cause and character of this flood becomes of special interest at this time because of the inauguration of the Muskingum Valley Project and proposals for the construction of an extensive system of flood-control reservoirs designed for the permanent prevention of floods in the Ohio River and its tributaries. Such a system would cost approximately $211,000,000 according to the estimate of Colonel Roger M. Powell, army engineer in charge of the Cincinnati office.[2] Under the proposed plan flood crests would be reduced some eight feet and river navigation would be facilitated by the maintenance of a standard water depth. The propensity of the Ohio River to flood is indicative of the need for control works. The complexity of the natural phenomena which lead to flood conditions in the Ohio Valley suggests the need for a comprehensive study of the causal factors.

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[1]The writer wishes to acknowledge the assistance of Dr. Guy-Harold Smith, Department of Geography, Ohio State University, particularly in the preparation of the maps.

[2]The Enquirer, Cincinnati, May 3, 1934.

RECURRENCE OF FLOODS

Floods in the Ohio River Valley are not an unusual phenomena. River records for Cincinnati, located about midway between the mouth of the river and Pittsburgh, show that in the seventy-two-year period ending in 1931, flood stage has been reached at this point no less than thirty-five times. On this basis a flood may be expected about every other year. However, the river departs from the average in regard to the timing of its floods. On but eleven occasions has the flood occurred on alternate years. On five occasions floods have been separated by two-year intervals, once by a three-year interval and on two occasions five year periods passed without the river leaving its banks. Twice floods have occurred on three successive years and a four year period, ending in 1918, was featured by a flood each year.

The seasonal occurrence of high water shows less irregularity in the seventy-two year period under consideration. February leads with twelve floods, March is second with nine, January and April have six and five respectively, while December and August are each credited with one.

The Ohio River shows a great variability in the severity of its floods, not only as measured by comparisons of crest levels at a particular station, but also as measured by comparison of crest levels taken at several points along the stream. Cincinnati, taken as an example of a particular station, has recorded a total of thirty-five floods of which only two have approached a crest level of twenty feet above flood stage, and only six have reached a level of ten feet above the river's banks. In contrast, eighteen of the thirty-five floods recorded at this station have had a crest of less than four feet above flood stage. In regard to comparison of flood severity at selected points along the river, the March, 1933 flood produced the highest crest since 1913 for stations from Point Pleasant, West Virginia, to Shawneetown, Illinois. However, five floods at Pittsburgh since 1913 have exceeded the crest level of the 1933 flood at that point, while the flood of 1922 produced a higher crest at Paducah, Kentucky.

The character of the floods in the Ohio Valley as revealed by the existing records permit few valid generalizations, except perhaps, that floods do occur frequently. It is important, however, that the cause and character of these floods be deter-

mined and this information be used as a background for effective flood prevention and control works.

THE CAUSE AND CHARACTER OF THE MARCH, 1933, FLOOD

In the report of the United States Geological Survey on the Ohio Flood of 1913, the authors remarked that it was fortunate that the precipitation which caused the flood had occurred first on the lower tributaries of the river, giving them a chance to run out before the floods of the upper tributaries had entered the main stream. They suggested that the reverse might occur at some time with one flood reinforcing the other with disastrous results.[3] This forecast came true in the 1933 flood with the important exception that this most recent flood did relatively little damage.

Floods in the past have been due to a variety of causes, namely, excessive rainfall, rapid melting of accumulated snow, failure of reservoirs, forming and breaking of ice jams and breaking of levees.[4] The flood of 1913 resulted from excessive rainfall on saturated ground. The flood of 1933 resulted from exceedingly heavy precipitation, but its severity was intensified by the peculiar distribution of the rainfall in the middle and upper drainage basin of the Ohio River. There were two distinct rainstorms in the basin to which the flood may be attributed. The first storm occurred on March thirteenth, fourteenth and fifteenth, and the second on March eighteenth, nineteenth and twentieth, with a rainless period of about forty-eight hours intervening. During each storm rain was general over the entire drainage basin, but the maximum fall in the first storm occurred in the upper valley while that of the second storm was centered in the middle portion of the basin.

THE FIRST STORM

On March twelfth, the day prior to the first storm, the Ohio Valley experienced fair weather and rising temperatures. The river was at about average stage from Pittsburgh to Cairo, and the ground was not overly moist since precipitation for the preceding months of January and February was below normal for the greater part of the drainage basin. An extensive

[3]A. H. Horton and H. J. Jackson, "The Ohio River Flood of March-April, 1913." U. S. G. S., Water Supply Paper No. 334, 1913, p. 46.
[4]Ibid., p. 13.

low pressure area was moving eastward over the Northern Rocky Mountains. On Monday morning, March thirteenth, the first day of the first storm, this Low was centered over Iowa. Violent thunder storms occurred throughout the Ohio Valley and rain was general east of Louisville. The turbulent

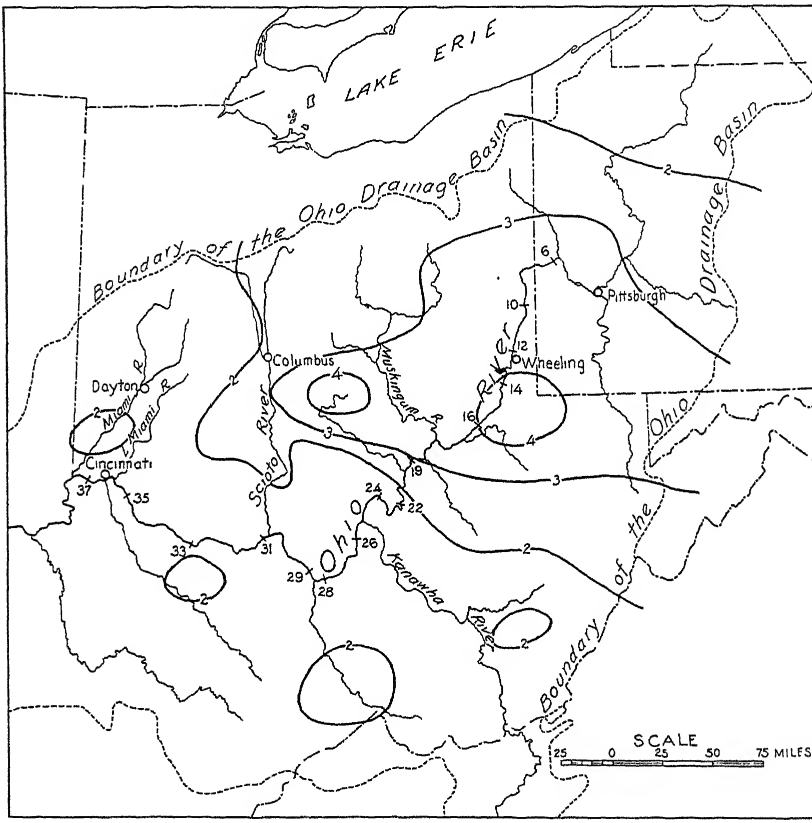

FIG. 1. Distribution of precipitation for March 13, 14, and 15, 1933. Note the heavy rainfall in the upper Ohio Valley with over four inches in the Wheeling district and on the headwaters of the Hocking River. (Numerals along the Ohio River indicate the location of dams.)

character of the atmosphere is indicated by the observations at Lunken Airport, Cincinnati. Calm wind was recorded at the surface while an eighty-three miles an hour gale was blowing at an elevation of 2,500 feet above the surface.[5]

[5]Daily Weather Map. Cincinnati Office of the Weather Bureau. March 13, 1933.

By the fourteenth, the second day of the storm, the Low had advanced to central Michigan and had developed a secondary which was centered over Arkansas. This trough of low pressure, crossing the Ohio Valley, brought the second day of general rain to the district. On the morning of the fifteenth the Low and its secondary had merged and were centered over eastern Pennsylvania. During the day the rain ceased and the skies cleared in the Ohio Valley.

The rainfall which accompanied the first storm reached its maximum amount in the Wheeling district and on the headwaters of the Hocking River, each district receiving about four inches of rain as a total for the three days. The average rainfall for the entire month of March is three and one-tenth inches at Wheeling and two and nine-tenths inches at Athens on the Hocking River. The distribution of rainfall in the Ohio Drainage Basin for the three-day storm period is indicated on Figure 1. The three-inch isohyet includes the greater part of the basin east of the Muskingum River, while the two-inch isohyet reaches as far west as Wilmington, Ohio. In addition, isolated areas receiving two or more inches of rainfall are found in the middle Ohio Valley.

The most notable feature in the distribution of the rainfall of the first storm is its maximum in the upper or eastern portion of the Ohio Drainage Basin.

THE SECOND STORM

The two-day interval between the rain storms was featured by the passage of two anti-cyclones in succession over the Ohio Valley. Moving in from the West Coast, however, was an extensive low pressure area that brought this period of fair weather to an end.

On the morning of the eighteenth this Low was centered over southern Kansas and covered the greater part of the United States with the exception of the Pacific Coast. An equally extensive high pressure area spread over Canada with its center north of Lake Huron. Under such conditions the predicted track of the cyclone led south of the Ohio Valley, probably through Tennessee. On the expectation that the northern section of the Low would pass over the valley, the Cincinnati Office of the Weather Bureau predicted unsettled weather for the eighteenth and clearing weather for the

nineteenth.[6] The Low, however, turned at right angles to its estimated course and moved north at a slow rate. The movement of the storm center from the eighteenth to the twentieth is estimated to be at a speed of about thirteen miles per hour or less than one-half the normal winter rate. From

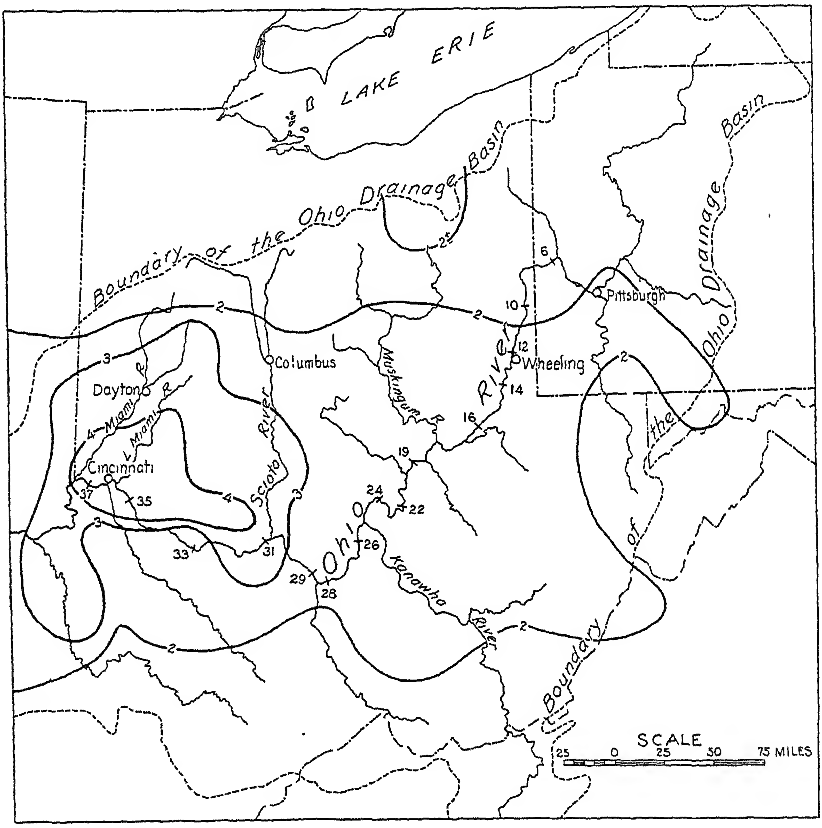

FIG. 2. Distribution of precipitation for March 18, 19, and 20, 1933. The rainfall of the second storm reached its maximum in the Cincinnati district. Compare with Fig. 1.

its position over Kansas on the eighteenth the Low moved over Cincinnati on the twentieth and on the twenty-first was centered over lower Michigan. From here it moved northeastward down the St. Lawrence Valley.

[6]Daily Weather Map. Cincinnati Office of the Weather Bureau, March 18, 1933.

The rainfall which accompanied the passage of this cyclone over the Ohio Valley began falling on the afternoon of the eighteenth and was general and more or less continuous over the entire valley until the morning of the twentieth. In contrast to the first storm, the maximum fall occurred in the middle rather than the upper valley, and the total amount for the three-day storm period was greater. (See Fig. 2.)

Five and two-tenths inches of rain fell at Cincinnati, the heaviest recorded in either storm. "The greatest rainfall [at Cincinnati] in thirty-six hours was nearly five inches, and the rainfall was at the rate of one inch per hour for a considerable time."[7] Two inches or more of rain occurred in nearly all of the Ohio Basin in the second three-day storm period.

The approach of a third storm in the series which brought flood conditions to the Ohio Valley in March, 1933, gave rise to the possibility of an even more severe flood than was experienced. This low pressure area was centered over northern Texas on the twenty-second of March and the presence of a high pressure area over Florida enhanced the probability of the movement of the storm area over the Ohio Valley. The prospect of a third rainstorm over the then flood-stricken district was regarded with apprehension. Special data on the progress of this low were collected by the Cincinnati Office of the Weather Bureau and two special Weather Maps were constructed in one day.[8] Fortunately, the storm moved eastward over Tennessee and the precipitation in the Ohio River Basin was negligible.

The total precipitation which fell in the upper and middle drainage basin of the Ohio River from March thirteenth to March twentieth amounted everywhere to more than three inches. Thus, in the area at large, the rainfall of an eight-day period about equaled the normal precipitation for the entire month of March. The maximum fall for the entire basin was in the Cincinnati district where seven and eighty-five hundredths inches were recorded. In the upper valley, Wheeling had a total of six and fifty-four hundredths inches, while near the mouth of the Muskingum River six and forty-two hundredths inches of rain fell in the two storm periods.

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[7]R. T. Zoch, "Monthly Weather Review." U. S. W. B., June, 1933, p. 16.
[8]The Enquirer, Cincinnati, March 23, 1933.

The fact that in this particular flood period the heaviest rainfall occurred within a few miles of the Ohio River itself acquires an added significance in regard to the proposals to control the flood waters of the Ohio by means of storage dams

	MARCH 13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		
Pittsburgh	-F	-R	+R	+F	-F	-F	-R	-R	-F	-F	-F	-F	-F	-F	-F	-F		
Dam 6	-R	-R	+R	+F	+F	-F	-R	-R	-F	-F	-F	-F	-F	-F	-F	-F		
Dam 10	-R	-R	+R	+R	+F	-F	-R	-R	-F	-F	-F	-F	-F	-F	-F	-F		
Dam 12	-F	-R	-R	+R	+F	-F	-R	-R	-R	-F	-F	-F	-F	-F	-F	-F		
Dam 14	-F	-R	-R	+R	+F	-F	-F	-F	-R	-S	-F	-F	-F	-F	-F	-F		
Dam 16	-F	-R	-R	+R	+F	+F	+F	-F	-R	-S	-F	-F	-F	-F	-F	-F		
Dam 19	-F	-R	-R	+R	+S	+F	+F	+F	+F	+R	+F	-F	-F	-F	-F	-F		
Dam 22	-F	-R	-R	-R	+R	+F	+F	+F	+S	+S	+F	-F	-F	-F	-F	-F		
Dam 24	-F	-R	-R	+R	+R	+R	+S	+S	+S	+S	+F	+F	-F	-F	-F	-F		
Dam 26	-F	-R	-R	-R	+R	+R	+R	+R	+S	+S	+F	+F	+F	-F	-F	-F		
Dam 28	-F	-R	-R	-R	-R	-R	+R	+R	+S	+S	+S	+F	-F	-F	-F	-F		
Dam 29	-F	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	-F	-F	-F		
Dam 31	-F	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	-F	-F		
Dam 33	-S	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F		
Dam 35	-R	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F		
Dam 37	-R	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F		
Dam 38	-R	-R	-R	-R	-R	-R	+R	+R	+R	+S	+F	+F	+F	+F	+F	+F	-F	
Dam 39	-R	-R	-R	-R	-R	-R	+R	+R	+R	+R	+S	+F	+F	+F	+F	+F	-F	
Dam 41	-R	-R	-F	-R	-R	-R	-R	+R	+R	+R	+R	+F	+F	+F	+F	+F	+F	-F

- Below Flood Stage   F River Falling
+ Above Flood Stage   R River Rising
S River Stationary

FIG. 3. Progress and duration of the flood. The broken lines inclose the periods of rising water, while the solid lines indicate the flood interval at selected stations along the Ohio River. Note the difference in the incidence and duration of the flood in the upper and middle valley.

on the headwaters of the major tributaries. The precipitation above the storage dams of the Miami Conservancy District averaged about three inches, while below the control works the rainfall for the flood period averaged about five inches. As a result of the peculiar distribution of rainfall in the Miami

Valley, minor overflows occurred in the vicinity of Middletown and Hamilton and the Conservancy Dams were of little, if any, benefit in retarding the progress of the flood waters of the Ohio River. On the contrary, it is possible that the channel improvement on the Miami River south of Dayton speeded the runout of its waters, thus intensifying the flood of the Ohio River.

PROGRESS AND DURATION OF THE FLOOD

On the morning of March thirteenth the Ohio River was at about average stage from Pittsburgh to Cairo. The general rains which accompanied the first storm began on the morning of the thirteenth and continued until the afternoon of the fifteenth, with the heaviest precipitation occurring in the upper portion of the valley. In response to this storm the river rose throughout its upper and middle course and on the morning of the sixteenth was above flood stage from Pittsburgh to Dam Twenty-four (Pomeroy, Ohio). At Louisville, Kentucky, however, the river was at approximately the same stage as on the preceding day. (See Fig. 3.)

During the interval of rainless weather which prevailed from the afternoon of March fifteenth to the afternoon of the eighteenth, the crest of the flood waters passed downstream bringing flood conditions to the valley from Dam Fourteen (St. Marys, West Virginia) to Dam Twenty-nine (Ashland, Kentucky). Above Dam Fourteen the river had subsided to within its banks while below Dam Twenty-nine, although the river was approaching flood stage, the prospect was for a flood of minor character. It was estimated by the Cincinnati Office of the Weather Bureau on the morning of the eighteenth that the approaching crest would bring the river to a level of about fifty-two feet or approximately flood stage at that point.[9] On the afternoon of the eighteenth the rains of the second storm began, and while general over the entire valley, reached their maximum in the Cincinnati District. The rapid inflow of water from this second storm reinforced the waters of the first and changed what promised to be a flood of minor character into one of major proportions.

Since the rainfall of the second storm was relatively light in the upper portion of the valley, it failed to bring the river

[9]Daily Weather Map. Cincinnati Office of the Weather Bureau, March 18, 1933.

to flood stage again upstream from Dam Fourteen. At Pittsburgh the river had fallen to a level of about seven feet below flood stage on the morning of the nineteenth. Twenty-four hours later the run-off of the upper tributaries had filled the channel to within two feet of flood stage, but the maximum flow of the stream passed without a second period of overflow.

Down stream from Dam Fourteen, where the effect of the first storm was still expressed either by flood conditions or rising water, the run-off of the second storm increased the height of the then existing flood and extended the flood zone to the vicinity of Louisville, Kentucky.

The influence of the dual storms is seen in the difference in the duration of the flood period in the upper and middle Ohio Valley. At Pittsburgh the river was in flood for two days, while at Dam Sixteen the overflow persisted for four days. Below this point where the waters of the first storm were reinforced by those of the second the flood interval was noticeably longer. Dam Nineteen experienced an eight-day flood or twice that of Dam Sixteen. Here the crest of the flood was reached on the sixteenth, early in the flood period, but subsidence of the river was so retarded by the second storm that flood conditions prevailed for six days after the crest had passed.

In the middle portion of the Ohio Valley where the flood waters of the two storms were merged, the flood period was from eight to ten days with the crest occurring about midway in the interval. At Cincinnati, the river passed flood stage between nine and ten o'clock on the evening of the eighteenth, soon after the second storm began, and rose at an average of about one-tenth foot per hour until the crest was reached at 5 P. M. on the twenty-first. This crest stage was held without noticeable change for fifteen hours. The run-out of the flood waters at this point required about five and one-half days after the river had started to subside. The tendency for the flood period to become progressively longer down stream is indicated further by the fact that the river remained above flood stage for ten days in the Louisville district as compared with a flood interval of fourteen days at Paducah, Kentucky. For a period of thirty days, beginning March fifteenth, the Ohio River at some point in its course from Pittsburgh to Cairo, was above flood stage.

Any plan designed for complete control of the waters of the Ohio must have multiple objectives. The control works must be comprehensive enough to retard effectively excessive stream flow when floods threaten. This will permit the development of riverine properly with a minimum of danger of loss from floods, and render navigation dependable in all seasons. Furthermore, the system of control works must be so planned that in periods of deficiency a river stage of depth sufficient for navigation may be maintained by increasing the discharge from the storage reservoirs. Such a plan implies an efficient and centralized control. It also implies, according to preliminary estimates, an expenditure of over $200,000,000. If the monetary cost of this vast project be balanced against the benefits which would accrue to the nation from a controlled Ohio River and the undertaking be found economically desirable, there still remains the development of an effective system of control works. The distribution and timing of the precipitation in the Ohio Drainage Basin which resulted in the flood of March, 1933, exemplifys but one of the many problems inherent in the control of the major stream through regulation of the flow of its larger tributaries.

Morphology of the Algae

Fritsch has added another distinguished volume to the subject of algology in giving us for the first time a comprehensive account of the morphology of the algae in the English language. The aim of the book is to present "a broad treatment of the subject-matter, such as will give a general review of the characteristics and interrelationships of the diverse group of Protista . . ." Phases of ecology, physiology, and taxonomy are dealt with only in so far as they are of general morphological interest. Some attempt is made to discuss the results of the vast number of cytological investigations. An introductory division of 59 pages discusses algae and flagellates, special structural features, and the general course of reproduction in algae. The classes of algae are then treated in more detail in order: Chlorophyceae, Xanthophyceae (Heterophyceae), Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonadineae, Eugleninеae, and the Colorless Flagellata. Volume II will presumably treat the Myxophyceae, the Rhodophyceae, and the Phaeophyceae.

The book is of the greatest value to morphologists and students of the algae in its organization of data amassed during the last three or four decades and in the very complete and carefully selected references to literature.

American algologists will be inclined to approve Fritsch's return to "Chlorophyceae" (instead of "Isokontae") and to his inclusion of Dinophyceae and Euglenineae in a discussion of algal relationships. One could wish for more of the clarity and artistry attained by the late Professor G. S. West in the numerous figures and plates in the present volume.—L. H. TIFFANY.

The Structure and Reproduction of the Algae, Vol. I, by F. E. Fritsch. xiii+791 pp. Cambridge, at the University Press; New York, the Macmillan Co., 1935. $8.00.

SOME INTESTINAL PARASITES OF *NATRIX SIPEDON* LINN., WITH NOTES ON THE IDENTITY OF *OPHIOTAENIA (TAENIA) LACTEA* LEIDY WITH *OPHIOTAENIA PERSPICUA* LARUE[1]

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The study on which this report is based was begun during the summer of 1929 at the Franz Theodore Stone Laboratory of Ohio State University at Put-in-Bay, Ohio. Additional material was collected from the same region during the latter part of the following summer.

Fresh water snakes of the species *Natrix* (*Tropidonotus*) *sipedon* Linn. were taken from the various islands of the Bass Islands region of Lake Erie. All of the organs usually inhabited by parasites were examined, but infestations were found only in the intestine. These species of parasites have not been previously reported for this host, though none of them were found to be undescribed species, with the possible exception of a single nematode of the genus *Camallanus*, as noted below.

The parasites found are as follows:

NEMATODA.

Camallanus sp.

A single male specimen, 10 mm. in length. The writer is unable to determine the species from the single specimen, or to state whether or not it is an undescribed species. Ward and Whipple list one nematode, *Physaloptera constricta* Leidy from this host species, but the specimen of this study is easily distinguished as of the genus *Camallanus* by the conspicuous lateral valve-shaped lips.

ACANTHOCEPHALA.

Leptorhynchoides (*Echinorhynchus*) *thecatus* Linton.

Natural host: various fresh-water fish.
Seventy-six specimens found in seven host specimens.
Heaviest infestation in single host: twenty-nine.

Acanthocephalans of this species were found in seven out of thirty-five host specimens, an incidence of twenty per cent. As many as twenty-nine were found in a single host. Identification of the species

[1]Contribution from the Zoological Laboratories of Northwestern University, Evanston, Illinois.

was checked by Van Cleave, who stated (in personal correspondence) that the infection in the snakes is very probably accidental, being acquired by eating the infected fish which are the natural hosts.

In addition to the adult specimens, large numbers of acanthocephalan cysts were found imbedded in the wall of the intestine in two of the host specimens. From the appearance of the proboscis and the size and number of the hooks in these cysts, they have been identified as being of the same species as the adults (*Leptorhynchoides thecatus*).

CESTODA.

Ophiotaenia perspicua LaRue.

Type Host: *Natrix rhombifer*.

Twenty-nine found in eleven of the thirty-five host specimens, an incidence of thirty-one per cent.

Heaviest infestation in single host: eight.

The only previous record of a cestode from *Natrix sipedon* is a description by Leidy (1855) of *Taenia lactea*. This description is so brief and so general as to be applicable to any species in the genus, and indeed to many others of the family Proteocephalidae. LaRue (1911) placed this as a *species inquirenda* in his genus *Ophiotaenia*. He later (1914: 208) suggested the probability of the identity of *O. lactea* with *O. perspicua*.

In view of the inadequacy of Leidy's description, it is impossible to state definitely whether the specimens found in this study are the same as his species. Since all of the cestodes found in this study were of the same species, however, it seems very probable that the one specimen found by Leidy in the same host species is the same. Furthermore, should another species of *Ophiotaenia* at any time be found in *Natrix sipedon*, it would be equally impossible to identify it with *O. lactea*. Hence, unless Leidy's type specimen can be produced for further study (LaRue states that it is not available—1914: 208), it is convenient and logical to assume the identity of the two species. It is therefore suggested that the name *Ophiotaenia perspicua* LaRue 1911 be retained for the species and that *Ophiotaenia lactea* (*Taenia lactea*) Leidy 1855 be considered a synonym, in recognition of complete, clear description, rather than of priority.

Although the dimensions of the tapeworms found in this study vary somewhat from those described for *O. perspicua*, there is no sufficiently outstanding difference to warrant the description of this form as a new species. The variations can be accounted for, in most instances, as due to differences in extension of the material at the time of fixation. In view of these differences, which may be noted in all platodes, a note of question of the infallibility of size alone as a diagnostic character of species is not out of order here.

The characters in which the measurements obtained by the present writer differ from those given by LaRue are listed and compared in Table I. The emended characters including the range of variations are also given.

TABLE I

Comparison of Characters of *Ophiotaenia perspicua* as Described by LaRue With Those Observed in This Study[2]

Character	LaRue	This Study	Emended Characters
Strobila	36 cm. × 2 mm.	3–60 cm. alive, largest 20 cm. when fixed.	3–36cm. × 2.5mm.
Neck	5–7 long × 0.17–0.425 broad	4–10 long × 0.185–0.5 broad	4–10 long × 0.17–0.5 broad
Mature proglottids.	2 × 2	1.4–2.4 long 1.2–2.2 broad	1.4–2.4 long 1.2–2.2 broad
Ripe proglottids	3.8 × 1.2	2–6.8 long 0.7–1.6 broad	2–6.8 long 0.7–1.6 broad
Head	0.344–0 408 broad	0.190–0.247 broad	0.190–0.408 broad
Suckers	0.105–0.17	0.088–0 129	0 088–0.17
Cirrus pouch	0.255–0.32 long 0.08–0.09 broad	0 3–0 4 long 0.05–0.14 broad	0.255–0.4 long 0 05–0.14 broad
Ratio, length cirrus pouch to width proglottid	3–4 (?)[3]	3½–6	3–6
Uterus, pouches on each side	20–30	23–32	20–32
Embryo, size	0.018–0.021	0 0148–0.022	0.0148–0.022
Eggs, size outer membrane.	0.045–0.1	0.066–0.125	0.045–0.125
Host	*Natrix rhombifer*	*Natrix sipedon*	

[2]All measurements in millimeters, unless otherwise stated.

[3]There appears to be a discrepancy in the figures given by LaRue at this point, for the maximum length of the cirrus pouch as given, divided into the breadth of the proglottid gives a larger figure.

The writer wishes to express his appreciation and thanks to Dr. F. H. Krecker, of Ohio University, for his interest and assistance in the survey portion of this research, and to Dr. H. J. van Cleave, of the University of Illinois, for the identification of the Acanthocephalan species.

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A VETERAN VOLUNTEER STATE SANITARY ASSOCIATION

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This is an account of the life-cycle of the Ohio State Sanitary Association which was born, flourished and died in the decade 1880–1890. The first and only secretary of the Association, R. Harvey Reed, M. D. (1851–1907), truly and fittingly called it at the time of its demise "a veteran volunteer sanitary association."

Few people in Ohio have any knowledge concerning this episode in the history of the state which brought together medical and lay representatives to labor for the creation of a state-wide program of health protection and promotion. This statement is especially true in the present day. We are so accustomed to the multiplicity of local, state and national health organizations which have appeared since the turn of the century that we are prone to assume that nothing existed before their establishment (1).

There is no complete record of the Association to be found anywhere. Broken files of the "Abstract of Proceedings" are held by several libraries (2). Fugitive references are to be found in the medical and sanitary journals of that day. In the early annual reports of the Ohio State Board of Health occasional references to the Association will be found (3). These references are so fleeting that they arouse a natural curiosity to know more about the Association.

The main reasons which brought about the organization of the Association seem to have been three in number. First, the deleterious effects, both socially and commercially, of recurrent epidemics with which the early settlers of Ohio had to struggle; second, the experience of the more populous centers in the state in attempting to curb epidemics and to improve insanitary conditions; and, third, the pressure from neighboring states which had established a state authority to bring order out of chaos.

Beginning with the establishment of the Northwest Territory in 1787 and continuing to the year 1852, the people of Ohio accepted the suffering and death which accompanied the regular appearances of epidemics with more or less fatalistic resignation. No one, not even the physicians, seemed to know what to do to combat them. The ideas, then prevalent, as to the causes of the swift and devastating rise and fall of the epidemic diseases were vague and confused. Practically all of the explanations had reference to the environment—exhalations from swamps or sewers; damp cellars; foul odors; filth; faulty drainage; faulty ventilation; and the changing climate.

In 1852, the Ohio General Assembly passed the first public health organization statute in the history of the State. It permitted cities to establish local boards of health if they so desired. Their chief functions were to abate nuisances and to enforce quarantine and isolation regulations. Further extension of this idea was made in 1875 when townships were permitted to establish local boards of health (4).

After the establishment of the Massachusetts State Board of Health in 1869 the idea of state control of health matters spread rapidly throughout the entire country (5).

Michigan, 1873; Kentucky, 1878; West Virginia, 1881; Indiana, 1881, and Pennsylvania, 1885, established boards modeled along the lines laid down in Massachusetts. Ohio, which did not establish such a board until 1886, was under continual criticism from these surrounding states, particularly West Virginia, because of the natural trend of travel to the east over the National Road and the consequent spread of epidemics from Ohio into that state.

Agitation for the establishment of a State Board of Health in Ohio came from the progressive physicians and laymen of the state. It began in the '70's. The proceedings of the Ohio State Medical Society show the sporadic outcroppings of this agitation during these years (6). No organized attempt at this time, however, was made to create public opinion to bring about such a board.

Early in the '80's R. Harvey Reed, M. D., began the presentation of the general subject of sanitation before the Mansfield Lyceum and Reading Circle. It was here that the idea of the Ohio State Sanitary Association was discussed for the first time. Dr. Reed became the moving spirit in the organization (7).

An editorial written by James F. Baldwin, M. D., editor of the *Columbus Medical Journal*, in January, 1884, gives the first announcement of the organization of the Association:

> There will be a Sanitary Convention in this city (Columbus), February 14 and 15. The convention will occupy two days, so as to afford time for the numerous papers that have been promised, and for action on the reports of important committees which will be appointed on the first day. A permanent organization is to be made which shall act as parent to local boards to be organized later in the year.
>
> This proposed organization is designed to take the place, so far as may be, of a State Board of Health, which Ohio ought to, but does not, possess. It is hoped and expected, however, that such a board will be the outgrowth ultimately of the present movement.
>
> A local association at Mansfield, headed by R. Harvey Reed, has initiated the present movement which bids fair to be a remarkable success (8).

In the same issue of the *Journal* the complete program for the two days' Convention is given. The announcement of the meeting is signed by Robert Harvey Reed, M. D., acting secretary, Mansfield, and James F. Baldwin, M. D., Columbus; Charles A. L. Reed, M. D., Hamilton; S. H. Smith, M. D., Warren; Elisha H. Hyatt, M. D., Delaware; and William W. Jones, M. D., Toledo, as a Counseling Committee (9).

The first meeting was held on February 14, 1884, at the Board of Trade, Columbus (10). The meeting was to have begun at 10:00 A. M., but was delayed in convening due to the difficulties delegates experienced in traveling caused by floods all over the state. Dr. J. F. Baldwin presided and welcomed the delegates to the city and the meeting. "The object of the meeting was to educate the people by the diffusion of a more thorough knowledge of the laws of health and the best means to be adopted for the prevention of all preventable diseases, and finally the securing of proper and wise legislation for the support of the same."

Wm. Morrow Beach, M. D., London, was elected temporary chairman and R. Harvey Reed, M. D., Mansfield, temporary secretary.

A Committee on Permanent Organization was then appointed consisting of: James F. Baldwin, M. D., Columbus; Xenaphon C. Scott, M. D., Cleveland; Elisha H. Hyatt, M. D., Delaware; Gustavus S. Franklin, M. D., Chillicothe; and Charles A. L. Reed, Hamilton.

The afternoon session was given over to Dr. X. C. Scott, who explained his bill "to establish Boards of Health and Medical Boards of Examiners and Licensers and regulating the practice of medicine and surgery in the State of Ohio and defining the powers and duties of such boards." A lively discussion then ensued, entered into by: Dr. E. H. Hyatt, Delaware; Dr. William J. Conklin, Dayton; Dr. John McCurdy, Youngstown; Dr. C. A. L. Reed, Hamilton; Dr. J. F. Baldwin, Columbus; Dr. R. D. Silver, Sidney; Dr. R. Harvey Reed, Mansfield; Dr. C. E. Beardsley, Ottawa; Dr. David H. Beckwith, Cleveland; Dr. H. J. Sharp, London, and Dr. Gustavus S. Franklin, Chillicothe.

An evening session was held in the hall of the House of Representatives, State House, at which time a general discussion was led by Starling Loving, M. D., Columbus, on the subject, "Resolved, That Legalized State Sanitation has Become a Necessity in the State of Ohio for the General Protection of its Citizens." Members of both houses of the State Legislature were especially invited.

On the morning of February 15, 1884, the report of the Committee on Permanent Organization was made and adopted.

For Officers:

President—Wm. Morrow Beach, M. D., London.
First Vice-President—Prof. Edward Orton, Columbus.
Second Vice-President—Prof. E. T. Nelson, Delaware.
Third Vice-President—Hon. L. D. Brown, Hamilton.
Secretary—R. Harvey Reed, M. D., Mansfield.
Treasurer—Prof. John Simpson, Mansfield.

For Committees:

Executive Committee which, ex-officio, includes all the presidents and secretary together with Starling Loving, M. D., Columbus; David H. Beckwith, M. D., Cleveland; William J. Conklin, M. D., Dayton; E. H. Hyatt, M. D., Delaware.

Committee on Publications—R. Harvey Reed, M. D., Mansfield; James F. Baldwin, M. D., Columbus; Geo. A. Collamore, M. D., Toledo.

Committee on Legislation—Wm. Morrow Beach, M. D., ex-officio, London; X. C. Scott, M. D., Cleveland; Charles L. Van Pelt, M. D., Toledo; and C. M. Finch, M: D., Portsmouth.

The Committee also reported on the Constitution and By-Laws as follows:

Name—The Ohio State Sanitary Association.

Object—The general advancement of sanitary science and the encouragement and promotion of local organizations throughout the state.

Members—Active, who shall form the body of the Association and shall be selected with special reference to their interest in sanitary and allied studies.

Honorary, who shall be selected with reference to their general interest only in the work in hand.

Meetings—At least once a year in the month of February and unless some other city is mentioned it will meet in Columbus.

The report was unanimously adopted.

The remainder of the meeting was given over to the reading of papers and discussion, the most important of which for our purposes were: David N. Kinsman, M. D., Columbus, "Some Reasons for the Establishment of a Board of Health;" Lewis C. Slusser, M. D., Canton, "Vital Statistics;" and Wm. Morrow Beach, M. D., London, gave his presidential address on "The Importance of Sanitation" (11).

The pertinent facts about the Association in subsequent years are briefly recorded together with the more important references.

Meetings (12)

1st —1884, February 14–15.	Board of Trade, Columbus.
2nd—1885, February 5– 6.	Board of Trade, Columbus.
3rd—1886, February 24–25.	Board of Trade, Columbus.
4th—1887, February 10–11.	Board of Trade, Columbus.
5th—1888, February 9–10.	G. A. R. Hall, Toledo.
6th—1888, November 14–15.	Assembly Room, City Hall, Canton.
7th—1889, November 21–22.	Y. M. C. A., Dayton.

Presidents—Listed in year elected.

1st —1884.	Wm. Morrow Beach, M. D., London.
2nd—1885.	Edward Orton, LL. D., Columbus.
3rd—1886.	Henry J. Herrick, M. D., Cleveland.
4th—1887.	Prof. E. T. Nelson, A. M., Ph. D., Delaware.
5th—1888.	George C. Ashmun, M. D., Cleveland.
6th—1888.	David H. Beckwith, M. D., Cleveland.

Secretary

1st–7th—1884–1889. R. Harvey Reed, M. D., Mansfield.

The main objective of the Association was reached when on April 14, 1886, the General Assembly of Ohio passed an "Act—To create and establish a State Board of Health in the State of Ohio" (13). Members of the first board appointed by Governor Joseph Benson Foraker on April 23, 1886, were:

W. H. Cretcher, M. D., Bellefontaine; T. Clarke Miller, M. D., Massillon; John D. Jones, M. D., Cincinnati; Simon P. Wise, M. D., Millersburg; David H. Beckwith, M. D., Cleveland; Thomas C. Hoover, M. D., Columbus; H. J. Sharp, M. D., London; and Hon. J. A. Kohler, Attorney General, ex-officio (14). On May 18, 1886, the permanent organization of the board was effected (15).

It will be observed that four of these appointees—Cretcher, Miller, Beckwith and Sharp—had been intimately identified with the Ohio State Sanitary Association. The other three appointees—Jones, Wise and Hoover—had been more or less interested in sanitary matters either locally or through the Ohio State Medical Society.

From the time the State Board of Health was organized until the demise of the Ohio State Sanitary Association on November 22, 1889, there appears to have been decided differences of opinion as to just what place the Association had in the public life of the state. There were also equal difficulties with respect to the Ohio State Medical Society.

An early evidence of this situation is contained in a resolution passed by the State Board of Health to the effect "that no papers shall be published in the Annual Report of this Board, except such as are ordered or approved for purposes of such publication by a majority of the members of the Board; and that any such paper shall be published over the signature of the writer, who is entitled to the credit of its production, as well as responsible for the statement of facts and opinions expressed therein." (16).

Another evidence is contained in the annual address of T. Clarke Miller, M. D., president of the State Board of Health, delivered in Columbus, November 17, 1887:

> The tendency to truculent criticism probably reached its climax when an eminent member of the profession, in a meeting of the Ohio State Medical Society, realizing his prominence and influence, bitterly assailed the personnel of the Board, and the motives which ruled in its selection. A resolution which appears in the "subsequent proceedings" indicates the profound impression made by the eloquent assailant of the Board (17).

The subsequent proceedings referred to Dr. H. J. Herrick, who offered the following resolutions, which, on motion of Dr. A. B. Carpenter, were adopted without discussion:

> WHEREAS, our legislature has enacted statutes creating a State Board of Health, and in conformity with said enactment, His Excellency, Governor Foraker, has selected men of intelligence, professional skill and integrity for the several positions on said Board; therefore,
>
> *Resolved*, That the State Medical Society cordially endorses the spirit and labors of the Board of Health in its arduous duties.
>
> *Resolved*, that we approve, and will individually co-operate with the Board in its purpose to diffuse the principles of sanitary service, by all means proposed, especially by distributing tracts among the people and special meetings for the enlightenment of the people on subjects of sanitary science.
>
> *Resolved*, That we recommend that the Legislature so increase their power that they can enforce provisions for the maintenance of public health.

Again:

> The work of the "State Sanitary Association" is worthy of special consideration on account of its annual contribution of many valuable papers to current sanitary literature; . . .
>
> It is hardly conceivable that self-aggrandizement should be the animus of any considerable proportion of the membership of this association; on the other hand, it cannot be doubted that, in the main, its members are actuated by a desire to promote the best interests of the people; this being the case, it is hoped that some satisfactory way may be found to place the more important of these papers within the reach of the people without expense to the writers . . . (18).

Steps were taken by the Association in 1887 looking toward making it an auxiliary to the State Board of Health. At the November 16, 1887, meeting of the State Board of Health, "a communication was presented from the Secretary of the Ohio State Sanitary Association relative to the publication of papers read before the Association in the annual report of the Board. Dr. Miller stated that at the last meeting of the Association . . . he had informed the Association . . . that the Board would be pleased to publish good papers not published elsewhere. Dr. Beckwith presented a communication from Prof. E. T. Nelson, President of the Sanitary Association. Dr. Nelson had been appointed to the Board in 1888 to succeed Dr. T. Clarke Miller, whose term expired, relative to a joint meeting of the Board and Association . . ." (19).

At the April 19th, 1889, meeting of the State Board of Health "a communication from Dr. Reed, Secretary of the Ohio State Sanitary Association, was read in which was given the action

of the Association in regard to making it auxiliary to the State Board of Health. The matter was referred to a Committee—Prof. E. T. Nelson and Dr. H. J. Sharp—with instructions to report at the next meeting of the Board." (20).

On June 19, 1889, Prof. Edward T. Nelson submitted a report from the committee appointed to consider the proposal to make the Ohio State Sanitary Association auxiliary to the State Board of Health. He said he had letters from a number of prominent members of the Association and all seemed to favor allowing the Association to come to an end as the State Board of Health could now carry on its work. The committee was not favorable to this proposition, but recommended that the State Board should pledge itself to carry on the work of the Association and hold one annual convention to which all sanitarians should be invited. Dr. W. H. Cretcher, M. D., Bellefontaine, spoke in favor of the report but did not consider it necessary for the Board to pledge itself to hold an annual convention, or to specify how it would carry on the work of the Association. With this amendment he moved the adoption of the report. The motion prevailed (21).

At the meeting of the Association on November 22, 1889, a committee consisting of T. Clarke Miller, M. D., Massillon; R. Harvey Reed, M. D., Mansfield; and Lewis C. Slusser, M. D., Canton, reported. A majority, consisting of Drs. Reed and Slusser, proposed the following resolution:

> WHEREAS, The Ohio State Sanitary Association was one of the pioneer organizations of its kind in this country and was organized nearly a decade of years since, for the purpose of "diffusing among the people a greater knowledge of the laws preventing all preventable diseases" and thus secure "proper and wise sanitation, systematically and scientifically administered," and
>
> WHEREAS, It has by these means been the active power in the creation of a State Board of Health, and has very materially aided in moulding public sentiment until better local sanitary laws have been enacted, and the organization of more effectual local boards of health in support of and in co-operation with the said State Board of Health has been accomplished all over our state; and
>
> WHEREAS, This "Veteran Volunteer Sanitary Association" of the State of Ohio has accomplished all the objects of its organization, and thus having fulfilled in an earnest, active, energetic and faithful manner the purposes for which it was created; therefore
>
> *Resolved*, That when all the business pertaining to the seventh annual meeting of this Association shall have been accomplished and the said Association is ready for adjournment, that the Ohio State Sanitary Association do then adjourn *sine die*.

A minority report was submitted by T. Clarke Miller, M. D., Massillon, who was chairman of the committee. He offered the following substitute resolution:

> WHEREAS, Independence is necessary to the efficiency of this organization,
> WHEREAS, "Support" has not been asked, and "co-operation" has not been thought of,
> *Resolved*, That "it would not be well for this Association to merge its efforts into a support of, and a co-operation with, the official forces of the State."

Upon debate George C. Ashmun, M. D., Cleveland, offered an amendment to the majority report which was accepted by Dr. Reed on the part of the committee. The amendment was:

> WHEREAS, The State Board of Health has provided for not less than two popular sanitary conventions each year; therefore be it
> *Resolved*, That we request the State Board of Health to arrange for not less than one meeting each year of the various local health officers of the state, and with this understanding, when all the business of the seventh annual meeting of the Ohio State Sanitary Association shall have been transacted, and it is ready for adjournment that it shall stand adjourned *sine die*.

In discussing the report and the amendment Dr. Reed said that "the prime object in organizing the Association had been to get at something definite and tangible in sanitary matters, and as such the result had been the organization of the State Board of Health. He now thought the objects had been accomplished and it was time to turn its labors over to the care and keeping of the Ohio State Board of Health." (22).

The majority report as amended was then unanimously adopted and a motion by Dr. Reed to adjourn *sine die* was carried. After which the members were taken in special cars to the Insane Asylum, where a reception and luncheon had been arranged for them.

And thus the Ohio State Sanitary Association passed into the limbo of all but forgotten episodes in the life of the people of Ohio.

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Ice

This intriguing book by Reginald Aldworth Daly, of Harvard, is the written material of the Silliman Lectures which he delivered at Yale University in 1934. The book is concerned with the last ice age, and describes the advance and retreat and various water bodies and changes of water bodies which have taken place during the ice age. There are seven chapters The first considers the melted ice-caps and the present ice-caps. The second chapter discusses the recession of the Fennos Canadian ice; the third, the recession of the North American ice. In the fourth Daly considers the Mechanism of the Earth's deformation and recoil Here are taken up the ideas of the effects of the great weight of ice on the geoid of the earth as it pushed down on the continents while the floors of the oceans were unloaded by a layer of sea water some 45 to 50 meters thick. Here we find the punching hypothesis favored over the idea of plastic recoil The punching hypothesis makes use of a hinge zone at the margins of the ice. The supporting evidence for this hypothesis seems very strong. In chapter five the high sea levels of the Pleistocene are studied and in chapter six the low sea levels are taken up. Chapter seven, which is perhaps the most important problem, deals with Coral Reefs and the Ice Age. Here Daly gives very strong evidence in the Glacial Control Theory for the origin of our present coral reefs. This theory considers that the coral reefs got their start on wave cut platforms which were developed during the low Pleistocene sea levels and which grew up as the seas slowly filled. It is supported by numerous examples and it does not face the many difficulties of the classic theory of Darwin and Dana.

This is an exceedingly scholarly and readable discussion of the Ice Age. The illustrations are excellent, and with a few exceptions, opposite the pages where the discussion concerning them occurs. Some 29 tables summarize various types of data such as ocean temperatures and the like. Every one interested in Pleistocene history will get a new sense of proportions of this changing world. The numerous facts sorted out and used in support of the several theories, give an insight into the magnitude of the problems. There are geologists who will not agree with the author in various aspects of glacial history, but in spite of differences of opinion this is an extremely valuable work and will have many followers.

—WILLARD BERRY.

The Changing World of the Ice Age, by Reginald Aldworth Daly. xxii+271 pp. New Haven, Yale Univ. Press, 1934. $5.00.

NOTES ON THE INFESTATION OF WILD BIRDS BY MALLOPHAGA[1]

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During the past five years while collecting birds for various scientific purposes, such as museum skins and mounts and parasite studies, records were kept on the infestation of these birds by Mallophaga. The birds were collected from various localities in Ohio, with the bulk of them taken at Buckeye Lake and in central Ohio, by the writer and others. For the opportunity to examine birds taken by other collectors I am indebted to Mr. Milton B. Trautman, formerly of the Ohio Division of Conservation, and to Mr. Charles F. Walker, of the Ohio State Museum. I thank Mr. Edward S. Thomas, of the Ohio State Museum, Mr. Milton B. Trautman, and Mr. Harold S. Peters, of the Bureau of Entomology, for their critical reading of this paper.

In this work a bird was considered to be infested with Mallophagan parasites if any stage in the life cycle of the insect was found on the bird. To date a total of 1,025 birds have been examined.

Nine of the 19 orders of birds are represented by these 1,025 individuals, of which the Passeriformes include more than half the total number. The nine orders are: Ciconiiformes, Anseriformes, Falconiformes, Galliformes, Gruiformes, Charadriiformes, Cuculiformes, Piciformes and Passeriformes. Table I gives the orders together with the individuals examined and the number infested.

The total infestation of the first eight orders was 178 birds out of 315 examined, or 56.5 per cent. The number of birds from each of these orders was admittedly too small to draw a definite conclusion. However, since these specimens were collected from many localities in Ohio during a five-year period, it would seem that a general idea of the amount of infestation might nevertheless be obtained.

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[1]Contribution Number 3, new series, from the Department of Zoology, Capital University, Columbus, Ohio.

It has been frequently stated that aquatic birds are more often parasitized than land birds, due to the more humid environment of these groups. If the following orders are considered to include aquatic birds, Ciconiiformes, Anseriformes, Gruiformes, and Charadriiformes, out of 97 examined, 56 individuals were found to be parasitized, or 57.7 per cent. If this is compared with the infestation of the entire first eight orders there is a difference of only 1.2 per cent in favor of the aquatic birds.

If we may consider the Falconiformes and Galliformes as large land birds, and compute the per cent of infestation in

TABLE I

Order	Individuals Examined	Individuals Parasitized	Per Cent of Infestation
Ciconiiformes	9	4	44.4
Anseriformes	21	16	76.1
Falconiformes	18	9	50.0
Galliformes	153	99	64.7
Gruiformes	5	5	100.0
Charadriiformes	62	31	50.0
Cuculiformes	4	2	50.0
Piciformes	43	12	27.9
Passeriformes	710	292	41.1
Total	1,025	470	Average 56.0

these groups, it is found that of 171 birds examined 108 were parasitized, or 63.1 per cent. This is 5.4 per cent more than in the aquatic group. Thus it would seem that the humidity factor is not as important as generally considered. Taking the Cuculiformes, Piciformes and Passeriformes as small land birds, from 757 of these, 306 were parasitized giving a percentage of 40.4. These figures show that in this case at least, the large land birds are more heavily parasitized than the other groups.

Another statement that has been commonly made in the literature is that gregarious birds are more often parasitized than non-gregarious birds. Of the orders represented, the Ciconiiformes, Anseriformes, Galliformes and Charadriiformes are the only ones which may be definitely considered gregarious. Combining these groups, of 245 birds examined 150 were parasitized, or 61.2 per cent. Considering the others non-

gregarious, 320 of 780 birds were parasitized, 41 per cent. These results tend to show that the gregarious habit is probably an important factor in the transmission of Mallophaga from host to host.

About 137 species of Passerines are found commonly in Ohio. Of this number, 710 individuals of 120 species, have been examined. In the Passeriformes the Hirundinidae, Corvidae, Laniidae, Sturnidae, Vireonidae and Icteridae show the heaviest infestation. Of these the Laniidae and Vireonidae are not gregarious. Computing the amount of parasitism in

TABLE II

Family	Individuals Examined	Individuals Infested	Per Cent Infestation
Tyrannidae	34	9	26 5
Alaudidae	25	3	12 0
Corvidae	16	10	62 5
Sturnidae	76	65	85 5
Icteridae	203	90	44 3
Fringillidae	105	39	37 1
Tangaridae	6	1	16 6
Hirundinidae	15	8	53 3
Bombycillidae	10	1	10 0
Laniidae	4	3	75 0
Vireonidae	16	8	50 0
Mniotiltidae	115	30	26 0
Motacillidae	1	0	none
Mimidae	10	6	60.0
Troglodytidae	15	6	40 0
Certhiidae	8	0	none
Sittidae	5	0	none
Paridae	13	1	7 6
Sylviidae	14	4	28 5
Turidae	19	8	42 1

the gregarious families, of 310 birds 173 were parasitized, or 56 per cent. Now computing the infestation of those families most often parasitized, but not gregarious: 19 birds, 10 infested, or 52.5 per cent. Results here again show that the gregarious habit tends to increase the infestation. Table II shows the numbers by families in the order Passeriformes.

From the data obtained in this study it would seem that the parasite life cycle extends over the entire year, since eggs and lice, or, eggs or lice, may be found on the same bird species during the entire year and is thus not seasonal. The birds examined during the winter months had few or no adults and

nymphs and usually many eggs, while the same species examined in early spring were found to have eggs and nymphs. In late spring and early summer the adults were numerous as were the nymphs and eggs, while in late summer and early fall the adults decrease in number and the eggs increase in abundance. It seems likely that the parasite cycle should be continuous throughout the year due to the comparative changelessness of the insect's environment. If, however, the weather was very cold the number of adults found on the birds was smaller. Probably in very cold weather even though the temperature of the bird remains practically the same the adult insects cannot live while the eggs carry the species over.

In as much as Mallophaga are seldom found living off the bodies of their hosts, the dispersal of the various species must depend upon bodily contact among the individual birds. However, the opportunities for bodily contact are not numerous. They are probably limited to roosting, nesting, copulation and from prey to predator.

There are a few records in the literature where Mallophaga have been found on birds of prey which undoubtedly came from the prey unless straggling occurred. It is believed this rarely occurs and no such cases were found in any of this work.

In the case of copulation the opportunity for transmission is relatively short and it is questionable whether many parasites are thus transferred. Also in birds that mate for only one nesting season during a year the transmission in this manner would be slight.

The opportunity for transmission in roosting is greater. Migration of lice from one host to another probably takes place, for undoubtedly there is often contact of the bodies of the various individuals. Kellogg states that he has found pelicans, cormorants and gulls roosting together on the "bird rocks" off Monterey, California, and that he has taken *Esthiopterum toxocerum* Nitz., a parasite of the cormorants, on the pelicans, as well as on the cormorants. But even on these ocean rocks, after frightening away hundreds of these birds he has looked in vain for Mallophaga that might be wandering from host to host.

Perhaps the greatest opportunity for transmission is from adult bird to young during feeding and brooding. Particularly during brooding the time of bodily contact is longest and the opportunity for the lice to find new feeding grounds is greatest.

It might be expected then that birds reared by foster parents would have the parasites of these parents. The cowbird (*Molothrus ater ater*) would furnish a case of this kind.

Since cowbirds are parasitic on about one hundred species of Passerine birds, it might be expected that Mallophaga of the cowbird's hosts would be found on cowbirds. In all the literature, prior to 1930, there is but one record of a louse taken from a cowbird, and that is Kellogg's record of *Philopterus transpositus* (Kell.) taken in Kansas in 1896. This species is a member of Piaget's group *forficulati*, which had up to that time been found only on the Psittacinae. This group of insects has a forcipated clypeal front. Kellogg's species has never been taken since to my knowledge.

One hundred fifty-five cowbirds have been examined; 71 or 45.8 per cent of which were infested with Mallophaga. Adult lice were found on 42 of these 71. The following five species of Mallophaga were taken:

1. *Menacanthus persignatus* (Kell.). Type host, California jay. This species has been taken from six American Passerines of which three are hosts of the cowbird.

2. *Myrsidea incerta* (Kell.). Type hosts, Goldfinch and russet-backed thrush. This species has been taken from nine Passerines, seven of which are hosts of the cowbird.

3. *Philopterus subflavescens* (Geoff.). Type host, European white wagtail. Also taken from some 80 Passerines, 70 of which are cowbird hosts.

4. *Degeeriella illustris* (Kell.). Type host, Red-winged blackbird. This species has been taken from six Passerines, of which five are cowbird hosts.

5. *Machaerilaemus laticorpus* Carr. Type host, a South American vireo It has also been taken from two Passerines, both of which are hosts of the cowbird.

Of these five species, *Philopterus subflavescens* and *Degeeriella illustris* were taken the most often. From the above records it seems that the parasites of the cowbirds fall into three general groups: (1) parasites that are found only on Icterid hosts; (2) parasites that lack host specificity and are found on many Passerines; (3) others that do not regularly parasitize cowbirds. The first two groups rank approximately equal in numbers, the third group being much the smallest.

Bagnall (1931) made a similar study on the Mallophaga of the European cuckoo which is also parasitic. He found

these parasites to be distinctly peculiar to the cuckoo and not to the various hosts of the cuckoo.

Some experiments in temperature response were performed on *Degeeriella vulgata* (Kell.) taken from an English sparrow. Ten adult lice of this species were kept in the laboratory on English sparrow feathers at a temperature of 38 degrees C. for ten days. The average temperature of the host of this louse is approximately 42 degrees C. Another group of 15 parasites of the same species was subjected to a temperature of 48 degrees C. This latter group showed marked irritation and all died within a few hours, while the controls lived 12 days at a temperature of 38 degrees C.

In collecting some of the birds in this work their temperatures were taken immediately after being killed. This was done by means of a special clinical thermometer which was thrust down the throat of the bird into the proventriculus. It is well known that the temperature of a bird varies four or five or more degrees between periods of rest and those of activity. Kendeigh and Baldwin in a study of nestling house wrens found the body temperature of these birds to vary as much as 8 degrees F. Simpson and Galbraith found the daily variation in temperature to be greater in birds of small size than in those of large size. Wetmore made a study of the temperatures of birds using the same methods as outlined above.

Wetmore's data on temperatures were used to check the amount of variation among the birds parasitized by certain species of Mallophaga. In this study *Philopterus subflavescens* (Geoff.) was taken from 30 different species of birds. The average temperatures of these hosts vary from 107 degrees F. to 110.2 degrees F., a difference of 3.2 degrees. Similarly the temperatures of the birds parasitized by *Degeeriella vulgata* (Kell.) vary from 106.9 degrees F. to 110.2 degrees, a difference of 3.3 degrees. The temperatures of the Anserine hosts of the three common duck infesting Mallophaga, *Trinoton querquedulae* Linn., *Anatoecus dentatus* (Scop.), and *Esthiopterum crassicorne* (Scop.) vary from 105.8 degrees to 107.9 degrees, a difference of 2.1 degrees. The difference in any of these cases is not more than 3.3 degrees, while other studies show variations in bird temperatures of as high as eight degrees, depending on rest and activity.

The average temperature of the cowbird is 108.2 degrees F. If this temperature is compared with the temperatures of the

hosts of the four principal parasite species mentioned above very little difference is found. The temperatures of the hosts of *Menacanthus persignatus* vary from 107.6° to 109.7°; those of *Myrsidea incerta* from 107.9° to 109.3°; those of *Degeeriella illustris* from 107° to 109.6°; those of *Philopterus subflavescens* were given above. These temperatures vary only 1.5° either way from that of the cowbird.

TABLE III

	Tyrannidae	Alaudidae	Corvidae	Sturnidae	Icteridae	Fringillidae	Tangaridae	Hirundinidae	Bombycillidae	Laniidae	Vireonidae	Mniotiltidae	Montacillidae	Mimidae	Troglodytidae	Certhiidae	Sittidae	Paridae	Sylviidae	Turidae
Menopon	x		x		x	x								x	x					x
Colpocephalum			x		x	x														
Menacanthus					x	x						x		x						x
Myrsidea			x	x	x	x		x				x		x	x					x
Machaerilaemus					x	x														
Eureum								x							x					
Ricinus	x	x				x			x		x	x							x	x
Philopterus	x	x	x		x	x	x	x	x	x	x	x		x	x			x	x	x
Degeeriella	x		x	x	x	x		x	x	x		x		x		x		x		x

Temperature may be a factor in determining host specificity for parasitic species, but the data so far accumulated is insufficient to draw any conclusions. Furthermore, by moving in close to the body of the host or out to the surface of the feathers, the parasite might make a suitable response to a variation in the host's temperature. It is probable then that temperature may be a relatively unimportant factor in host specificity.

Since more than half the birds examined in this study belong to the order Passeriformes, it is of interest to note the distribution of the parasite genera on the various bird families. Of the four Mallophagan families infesting wild birds all are found on the Passerines except Laemobothriidae. Of the Menoponidae the genera Menopon, Colpocephalum, Myrsidea, Eureum, Machaerilaemus and Menacanthus are found on this

bird order. Of the Ricinidae only the genus Ricinus is represented. The genera Philopterus and Degeeriella of the Philopteridae are found on the Passerines.

The genus Philopterus is present on 16 of the 20 families. On one of the remaining four families, the Sittidae, there were no lice taken. This genus includes more species than any other genus of the family. Degeeriella was found on 13 of the 20 families.

In the family Ricinidae the single genus Ricinus is found on but eight of the 20 families and of these eight it is found chiefly on the Turdidae and Fringillidae.

In the family Menoponidae, Menopon is found on seven of the bird families; Colpocephalum on three; Menacanthus on five; Myrsidea on nine; Eureum on two; and Machaerilaemus on two. Table III shows this relationship in graphical form.

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Blood Will Tell

The newer knowledge of the blood groups has developed so rapidly in the past few years that an up-to-date revision of this subject becomes essential. Dr. Wiener has supplied this need in his volume dealing with the blood groups and blood transfusion. All the practical applications of the groups are fully discussed: transfusion, clinical medicine, forensic medicine and anthropology. The M-N reactions are fully explained and their legal applications illustrated with case histories. The heredity of the M and N agglutinogens, as well as the older A and B antigens, is fully elaborated. The book is well illustrated with photographs and diagrams. Physicians, lawyers, biologists and anthropologists will find it essential to have this book on their shelves.—L. H. S.

Blood Groups and Blood Transfusion, by Alexander S. Wiener, M. D. xiv+220 pp. Springfield, Ill., Charles C. Thomas, 1935.

A NEW CHICKEN LOUSE (MALLOPHAGA: PHILOPTERIDAE) FROM THE CANAL ZONE

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Three lots of biting lice collected from the heads of domestic chickens in the Canal Zone were found to include an undescribed species with a peculiar, sharply angulated head. These lice are described below as representing a new species. It was surprising to find the new louse and the tropical head louse, *Lipeurus tropicalis* Peters,[2] in each of these three lots of material. The common chicken head louse, *L. heterographus* Nitzsch, found in many parts of the world, was not present. We have previously found that where the tropical head louse occurs it entirely replaces the common head louse and is the only louse found on the heads of the chickens, so this is an unusual record.

Lipeurus angularis n. sp.

Described from 13 individuals collected from the heads of domestic chickens in the Canal Zone as follows: One male and two females from Pedro Miguel, Canal Zone, 1931, by L. H. Dunn (Bishopp No. 18437), from chickens in the market; one male and six females from Mt. Hope, Canal Zone, May 18, 1934, by F. C. Bishopp (Bishopp No. 22104), from chickens in a farmer's flock; and two males and one female from Balboa, Canal Zone, May 19, 1934, by F. C. Bishopp (Bishopp No. 22105), from chickens in a poultry dealer's flock, the chickens having been raised in nearby Panama.

DESCRIPTION OF MALE

Head about three-fourths as wide as long, angulated in front, slightly wider across temples than before trabeculae. Temples broadly rounded, with one long and one very short seta on each side. Posterior edge of head only slightly concave. Eyes clear and protruding, with a rather short dorsal seta. Mandibles with expanded base and rather unusual size. Color light brown, with dark brown lateral borders, fading to almost colorless at forward edge of head. Clypeal suture with peculiar fold-like rounded points. Antennae about as long as head is wide, reaching, if extended backwards, to posterior edge of prothorax. First

[1]Contribution from the Division of Insects Affecting Man and Animals, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.
[2]Peters, H. S. *Entomological News*, Vol. XLII (1931), pp. 195–199.

segment enlarged, slightly longer than segments 3, 4, and 5 combined, and bearing no process. Segment 2 about half as long as segment 1; segment 3 extended into a dorsal inwardly projecting hook, as shown in Fig. 1a.

Thorax about three-fifths as long as the head, pale brown in color with dark brown lateral margins. Prothorax about two-thirds as wide as head, and about twice as wide as long, the sides only slightly diverging

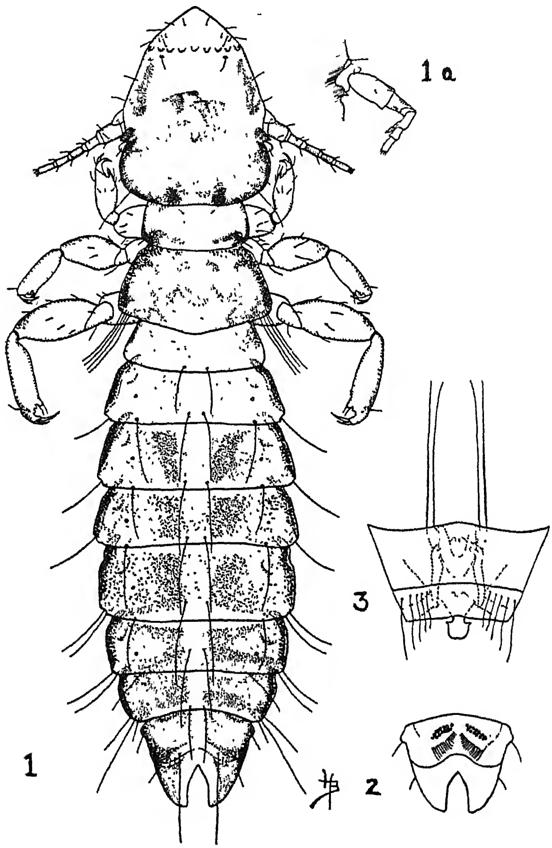

Fig. 1. *Lipeurus angularis* n. sp. Female, dorsal, × 38.
Fig. 1a. Antenna of Male, × 38.
Fig. 2. Posterior part of female abdomen, ventral, × 38.
Fig. 3. Male genitalia, dorsal, × 76.

posteriorly, the posterior edge slightly convex and with a seta at each latero-posterior rounded angle. Pterothorax slightly broader than head and half again as long as prothorax, sides diverging posteriorly, with rounded latero-posterior angles. Posterior edge slightly angulated on the abdomen, with a group of four long setae in a cleared area near each side. Legs pale with brown borders. Fore legs short, with the coxae

narrowly separated; middle and hind legs longer, hind legs longest and with widely separated coxae.

Abdomen of nine segments, elongate, widest at fourth segment, which is about one-third wider than the head. Ninth segment about three-fifths as wide as segment 8, with posterior edge slightly concave. From the sternum of the eighth segment there is a peculiar heavily sclerotized ball-like projection, studded with small spines on its surface, extending ventrally and posteriorly to the ninth segment, appearing as part of the genitalia and possibly functioning with it in copulation. Genitalia distinctive, edges of basal plate thickened and appearing as two rods extending forward into the sixth segment, endomeral plate horse-shoe-shaped, parameres separated and lying almost parallel, as shown in Fig. 3. Dorsal setae about the same as shown on the female in Fig. 1 and in Fig. 3. Light brown in color with dark brown pleurites forming a lateral band somewhat interrupted at the sutures. Lighter brown median markings, a clear space at the sutures, and a small clear area inside the lateral bands in which the small spiracles are situated on segments 2 to 7 inclusive.

DESCRIPTION OF FEMALE

Head slightly larger than in male. Antennae reaching, if extended backwards, slightly beyond posterior edge of head. Segment 1 swollen but equal in length to segment 2; segments 3 and 4 equal but shorter than 1 or 2; segment 5 slightly longer than 3 or 4.

Thorax and legs as in the male, except slightly larger.

Abdomen slightly longer and broader than that of the male. As shown in Fig. 1. Segment 9 deeply bilobed and bearing two combs of short setae ventrally, as shown in Fig. 2.

Average measurements in mm.

	Male Length	Female Length
Head	0 63	0 70
Thorax	.. 40	45
Abdomen	1 22	2.62
Totals	2.25	2.77

Type Host.—*Gallus domesticus*, chicken.

Type Locality.—Balboa, Canal Zone.

Type Slide.—Cat. No. 50787, U. S. National Museum.

The *holotype* male and the *allotype* female on the type slide were collected from chicken at the type locality on May 19, 1934, by F. C. Bishopp (Bishopp No. 22105) and are deposited in the U. S. National Museum. The *paratypes* are in the collection of the Bureau of Entomology and Plant Quarantine.

This species is very unusual in the sharply angulated front of the head, the very peculiar ball-like projection from the eighth sternite of the male, and the very deeply bilobed ninth abdominal segment of the female. This bilobed segment may

function in some way with the ball-like projection of the male during copulation.

L. angularis is easily distinguished from other lice found on the chicken. The head is more pointed and the size is smaller than in *L. tropicalis*, which is found commonly on the chickens in many tropical countries. It is also easily distinguished from the common head louse, *L. heterographus*, by the angulated front, the genitalia, and the posterior part of the female abdomen.

NOTE.—Since sending this paper to the editor I have received the following paper: "On a New Mallophaga (*Lipeurus denticlypeus* n. sp.) From the Formosan Fowl," by Masaatsu Sugimoto, from "Taiwan no Chikusan" (Animal Industry in Formosa), Vol. II, December, 1934. The description of this new species is written entirely in the Japanese language. Sugimoto's *L. denticlypeus* appears to be very close to my *L. angularis* but is slightly larger in size. It will be necessary to compare specimens of the two species to determine whether or not they are the same. It is quite interesting to find such similar lice on the heads of domestic fowls on opposite sides of the world.—H. S. P.

Biology for Today

High School teachers of Biology will do well to acquaint themselves with this new text in the field. It was written, according to the author's statements, after long experience and considerable study in the mechanics of textbook composition. The discussions are about equally divided as to plant and animal material. The style is simple. The non-technical vocabulary is limited largely to the "seven-thousand level" of Thorndyke's word list. There is a conscious effort to present an analysis of the scientific method of procedure and thought, and to stimulate the student to follow it in working with problematic situations as presented in the text and illustrations. Various biological principles are stated and labelled as such, and the student is asked to state them from time to time for himself. The student is asked to state hypotheses relative to certain situations and then to test these in various ways.

Aside from a few unfortunate instances, the book is relatively free from teleological statements. The chapters on behavior, on health and hygiene, on the conservation of natural resources and wild life, and Biology for leisure time, are especially commendable.

A work book and a series of objective tests accompany the text

—J. W. PRICE.

Biology for Today, by Francis D. Curtis, Otis W. Caldwell, and Nina Henry Sherman. xvi+692 pp. Boston, Ginn & Co., 1934.

ANTENNAL REGENERATION IN DAPHNIA MAGNA

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Antennal regeneration in Cladocera has been found to be rather variable. Przibram (1896, 1899) noted considerable variation both in amount and type of antennal regeneration in various species of *Daphnia* and *Simocephalus*. Kuttner (1913) found that antennal regeneration in *Daphnia magna* was extremely diverse. She noted that fully amputated segments never regenerated. Sciacchitano (1925) also pointed out that in *Ceriodaphnia pulchella* new segments of the antenna never formed. Setae were regenerated but never became as numerous, although often as large as the normal.

Recently Agar (1930, 1931) published some extensive researches on antennal regeneration in *Daphnia carinata* and *Simocephalus gibbosus*. His data show that the degree of variation in the amount of regeneration was high in spite of the fact that he limited the amputation to a specific level on a certain segment in each species and that the experimental conditions were very well controlled.

GENERAL OBSERVATIONS ON DAPHNIA MAGNA

When a ramus of an antenna is cut the distal end of the remaining stump turns brown within a few hours after the operation. The brown area is quite distinct from the rest of the stump. (Fig. 1.) The brown color is usually deepest at the proximal edge of the area. Late in the instar, provided the amputation was performed within the first half of the instar, a cleavage occurs between the brown area and the remainder of the stump. At ecdysis the brown material is cast off. During the next instar the injured ramus corresponds closely to that portion which was proximal to the brown area during the instar of amputation. A ramus may be cut in one segment and the brown area may extend down into the next. In such instances as well the ramus during the following instar always corresponds to that part which was proximal to the brown area.

A similar situation is found after the carapace is injured (Anderson and Brown, 1930; Anderson, 1933). When a small

area of the carapace is crushed with a ball-pointed needle a ring of brown material forms in the outer edge of the crushed area. At ecdysis this area is shed with the old chitin. During the next instar the wound corresponds closely to the area enclosed within and including the brown ring during the instar of injury. No part of the carapace need be removed to produce this phenomenon.

Further, no part of the antenna need actually be cut to cause the formation of brown material and the subsequent shedding of the portion of the antenna distal to and including

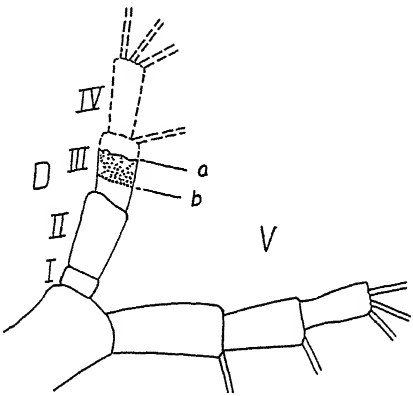

FIG. 1. An injured left antenna during the latter part of the first instar. A portion of the dorsal ramus was amputated early in the same instar Line *a* denotes the level of amputation. The dotted lines represent the part removed. Line *b* denotes the level of injury The stippled area between *a* and *b* is the brown portion—that injured by crushing in the amputation procedure.

the brown area. This was found by crushing part of the antenna sufficiently to injure the tissues but not break the chitinous cuticle. The area injured turns brown. The brown area together with the distal end of the antenna is cast with the rest of the old chitin at the next ecdysis. During the next instar the injured ramus corresponds closely to that part which was proximal to the brown area during the instar of injury.

Any amputation procedure involves the crushing of a part of the antenna before actual section is accomplished. Tissues proximal to the level of amputation are thereby injured. That part which is injured turns brown shortly after amputation. The brown color may be due to oxidized tyrosine in the clot of blood which forms in the injured portion (Pinhey, 1930).

The brown area probably corresponds to the necrotic area described by Agar (1930).

From the foregoing observations one may conclude that the injury is not limited to the level of amputation but extends to the proximal edge of the brown area. In making a quantitative study of the amount of regeneration the actual extent of the injury should be taken into consideration.

In order to determine the relation between the level of injury and the amount and type of regeneration the following series of experiments was performed.

MATERIALS AND METHODS

Females from a single clone of *Daphnia magna* Straus. were used. These were isolated within three hours after their release from the mothers and placed in a watch glass together with a few drops of culture medium. Just enough of a saturated solution of chloretone was added to render the animals immobile. Each animal was placed on its left side with the left antenna stretched out in front of the body. A specially ground steel needle was brought against the dorsal branch with enough pressure to sever it. The level of amputation was varied in each instance. After amputation each animal was placed in a vial containing approximately fifty cubic centimeters of fresh manure-soil medium (Banta, 1921). These were then allowed to remain at room temperature (18°–23° C.).

At least twelve hours after the time of amputation, but before the end of the instar, each animal was removed from its vial and placed in a watch glass together with a few drops of culture medium. Again just enough chloretone solution was added to bring about cessation of movement. After placing the animal on its left side with the injured antenna stretched out in front of the body, a camera lucida drawing of the amputated member was made. Care was taken to denote exactly the extent of the pigmented area. Immediately after making the drawing the animal was returned to its vial and allowed to remain until primiparous.

When the animal became primiparous the injured antenna was again drawn by following the same procedure as outlined above. Usually females bear their first clutch of eggs from six to eight days after their release from the mother when maintained at room temperature (Anderson, 1932). Those

which were not primiparous on the eighth day were discarded. This probably limited the data to those animals which passed through seven pre-adult instars or less.

From the first drawing the level of the injury was determined, i. e., the segment injured and the distance from the base of the segment to the proximal edge of the brown area. The obliquely bounded surfaces of the segments render measurement difficult. In each case the length was taken on the central axis of the segment. Uniformity of measurements was thus secured. From the second drawing, the length of the regenerated segment, the number of setae, and the length of the setae were determined. The length of the segment was taken in the same manner as in the first drawing.

Agar (1930) observed that the antennae change in size and shape only at ecdysis and immediately thereafter—they remain the same throughout the remainder of any instar. Drawings and measurements for any instar can therefore be made at any time during that period.

RESULTS AND DISCUSSION

The nature of regenerated antennae has been adequately described by Przibram (1896, 1899), Kuttner (1913), Sciacchitano (1925), and Agar (1930, 1931), and need not be detailed here. Regeneration is limited to the completion of the most proximal segment injured and the formation of new setae.

Agar (1930) considered only three measures of the amount of regeneration, namely: length of the antennal stump, number of setae, and length of setae. Of these he employed number and length of setae. In his estimation the stump was a poor criterion since regeneration involved only a slight growth of the operated segment. However, in *Daphnia magna* the volume of the regenerated material in the stump is much greater than that of the setae in most instances. On this basis one might conclude that the regenerated part of the stump would be a better criterion than that of the setae.

The amount of regeneration in the stump is not measurable directly. The segment in which regeneration has taken place may be looked upon as a product of both normal growth and regeneration. Normally a segment is about three times as long when an animal is primiparous as it is during the first instar. The difference between the length of the segment when an animal is primiparous and three times the length of the

uninjured portion during the first instar would then represent the amount of regeneration.

TABLE I

Summary of Data on Level of Injury and Amounts or Regeneration
(Lengths are in μ)

Level of Injury		Regeneration				
Segment	Level in Segment	Length of Segment	Calculated Segmental Regeneration	Number of Setae	Total Length of Setae	Number of Cases
I	Base	0	. .	0.0	0.0	4
II	Base	0	. . .	0.0	0.0	4
	1- 6	59 ± 15	50	1.25 ± .15	407 ± 44	4
	7-13	. .	. . . . . .	. .	. .	0
	14-19	136 ± 7	85	2.40 + .15	1020 ± 13	5
	20-25	127 ± 7	60	2 13 ± .16	770 + 60	8
	26-32	143 ± 6	53	2.33 ± .13	847 ± 64	6
	33-38	183 ± 10	77	2 50 ± .14	1127 ± 87	6
	39-45	169 ± 3	43	2.25 ± .28	910 ± 116	4
	46-51	199 ± 8	54	2.60 ± .15	1082 ± 15	5
	52-57	216 ± 14	51	3,00 ± .00	955 ± 83	3
	58-64	. .	.	. .	. . . . . .	0
	65-70	229 ± 5	29	3 75 ± .27	1394 ± 141	4
	71-76	216 ± —	0	4,00 ± —	1210 ± —	1
III	Base	0	. . . .	2 50 ± .13	1094 ± 72	12
	1- 6	0 ± —	0	2 00 ± —	738 ± —	1
	7-13	73 ± 6	43	2.00 ± .00	1062 ± 36	7
	14-19	93 ± 5	45	2.14 ± .14	1196 ± 91	7
	20-25	112 ± 6	53	2.40 ± .15	1275 ± 53	5
	26-32	140 ± 10	53	3.33 ± .37	1553 ± 146	3
	33-38	134 ± 6	26	2.70 ± .18	1375 ± 95	7
	39-45	135 ± 11	6	3.00 ± .00	1566 ± 3	2
	46-51	172 ± 6	25	2.00 ± .00	1146 ± 35	2
	52-57	169 ± 8	0	2.00 ± .00	1177 ± 31	2
IV	Base	0	. . . .	2.47 ± 14	1273 ± 79	15
	1- 6	20 ± 5	11	1.80 ± .30	802 ± 153	5
	7-13	69 ± 6	39	1.67 ± .13	815 ± 64	6
	14-19	93 ± 4	45	2 50 ± .12	1299 ± 55	8
	20-25	108 ± 10	39	2.75 ± .15	1458 ± 31	4
	26-32	96 ± —	9	3 00 ± —	1476 ± —	1
	33-38	99 ± 8	0	2.50 ± .24	1247 ± 79	2
	39-45	127 ± —	0	1.50 ± —	1081 ± —	1
Terminal Setae	. . . . .	. . . . .	. . . . .	2.75 ± .10	1578 ± 70	8

Table I summarizes the results. The level of injury is the level of the proximal edge of the brown material. Segmental

regeneration was calculated as proposed in the above paragraph. In those cases where the injury extended to the base of a segment that segment never regenerated. When the injury extended to the base of segment III or IV new setae were formed, but not when the injury reached the base of segment I or II. Removal of the terminal setae alone was followed by their regeneration. Whenever a part of segment II, III, or IV remained intact that segment exhibited regeneration and new setae were formed. Segment I was never regenerated nor were setae formed when the injury extended to that segment.

In general the length of the segment in which the regeneration occurred varied directly with the level of injury in the segment. The coefficients of correlation between the level of injury and the length of the segment were $+.76 \pm .04$, $+ .80 \pm .04$, and $+.73 \pm .06$ for segments II, III and IV, respectively. The amounts of regeneration varied inversely with the level of injury except when the injury reached the base of a segment or only a very small part of the segment remained intact.

Setal regeneration appears to fall into a different category. Each segment seems to present a specific problem. In the case of segment II the number of setae formed appears to be directly related to the level of injury. The coefficient of correlation was $+.67 \pm .05$. The total length of the setae was not so well correlated, $+.34 \pm .09$. For segments III and IV the maximum number of setae and also maximum total length of setae occurred when the level of injury was just distal to the middle of the segment. The coefficients of correlation were $+ .08 \pm .11$ and $+.39 \pm .11$ for number of setae and $+.31 \pm .10$ and $+.46 \pm .10$ for total length of setae for segments III and IV respectively.

The variations in the amount of regeneration reported by Agar (1930, 1931) are readily explainable. They are in all likelihood due to variations in the level of injury even though the level of amputation was kept constant. On the basis of the evidence presented in this paper one may alter Agar's (1930) statement from "the length of the segment left after operation is probably the most important single factor in determining the amount of regeneration" to—the length *of the uninjured portion* of the segment left after operation is probably the most important single factor in determining the amount of regeneration.

SUMMARY

The antennae of 150 female *Daphnia magna* were amputated at various levels during the early part of the first instar. In each case, within a few hours after amputation a brown pigment was deposited immediately proximal to the level of the cut. The extent of the brown area varied considerably. At the end of the instar the part of the antenna distal to and including the brown area was cast with the old chitin. During the next instar the antennal stump corresponded closely to that part of the antenna which was proximal to the brown area during the instar of amputation.

The amount of regeneration, as measured during the instar when the animals were primiparous, is qualitatively and quantitatively related to the segment in which the proximal edge of the brown area was located and to its level within that segment during the instar of amputation.

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WATER-VAPOR LOSS FROM PLANTS GROWING IN VARIOUS HABITATS[1]

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A plant's external and internal water relationships have been used extensively in explaining plant distribution. For more than a century botanists have measured transpiration from plants in various ways, resulting in a vast accumulation of data. However, most such measurements have been on plants growing in an environment quite different from that of their native habitats. It seemed desirable to make an extensive study of water-vapor loss from leaves of plants as they were growing in various plant associations. The habitats selected for this study were typical of the Deciduous Forest Formation of the Central States. These observations were made chiefly in Ohio and a few in the central part of Indiana, during the summers of 1927 to 1931 inclusive. The data presented were obtained from determinations upon one hundred and forty-eight species, belonging to sixteen plant associations.

The writer desires to take this opportunity to express his appreciation to Dr. E. N. Transeau, under whose direction this work was planned and carried out.[2]

METHOD USED

Determinations of the rate of water-vapor loss were made with standardized cobalt chloride hygrometric paper. This method was selected because it can be so readily applied to plants under field conditions. The measurements obtained are thought to be sufficiently accurate for problems in physiological ecology. The cobalt chloride method was originated by Stahl (10), later improved by Livingston (5), Bakke (1), Livingston and Shreve (6), and finally by Meyer (7). The hygrometric paper used in the following experiments was standardized quantitatively by Meyer's method.

[1]Papers from the Department of Botany, The Ohio State University, No. 344.
[2]This paper represents a portion of the dissertation offered as a partial requirement for the doctorate degree from The Ohio State University.

The cobalt chloride hygrometric paper was prepared and mounted on narrow strips of celluloid as suggested by Meyer. The paper was cut into discs $^{15}/_{32}$ inches in diameter and fastened to each end and on the same surface of the strips, by means of gummed reenforcements for notebook paper. These held the hygrometric paper pieces in position with only the one surface exposed, which was to be placed next to the leaf to be tested, and the other surface could be seen through the celluloid. The strips were then folded along the short axis through the center. This made a clip which could be readily clamped to a leaf with the sensitive paper exposed to each epidermal surface. Small clamps (Dennison's Card Holder No. 42) were found satisfactory for holding the clip in place on the leaf.

Small desiccators for drying the clips were made from 100 cc. wide-mouthed bottles, stoppered with paraffined corks. Anhydrous calcium chloride was used as the desiccating agent. Cotton was placed on top of the calcium chloride to prevent the paper from coming in contact with the calcium.

It should be emphasized that the method does not measure transpiration as it normally occurs, but it does measure water-vapor loss under a standard set of conditions. For this reason the water-vapor loss as measured by the cobalt chloride paper has been called "standard water-vapor loss" by both Meyer (7) and Blaydes (2).

It may be well to point out some of the conditions of the artificial environment produced by the hygrometric paper clips. When a clip is applied to a leaf, light is removed from that small area under the clip into which water-vapor is lost by the leaf. Wind can have no direct effect on the small portion of the leaf being tested. All measurements may be reduced to a standard temperature by Livingston and Shreve's (6) method. Humidity of the atmosphere about the leaf has little if any direct effect, for almost as soon as the desiccated hygrometric paper is applied to the leaf, the small space between the clip and the leaf registers close to zero humidity. Therefore, the leaf surface being tested at first loses water-vapor to a nearly desiccated atmosphere. As the determination continues, however, this atmosphere becomes more and more humid. This introduces some error since the diffusion gradient is gradually decreased. The results of measurements of the water loss from a plant living in a very humid environment will deviate more from true transpiration rate than will the result of such measure-

ment upon plants in a dry environment. That is, the water-vapor loss as measured is more nearly a determination of what the plant would lose under the drier condition of the atmosphere. Blaydes (3) has shown that amounts obtained by the cobalt chloride hygrometric paper method and the weighing method do not necessarily coincide.

STANDARD WATER-VAPOR LOSS MEASUREMENTS

The objective of this work was to determine whether the standard water-vapor loss from plants of various associations was an adequate measure or an indicator of the habitat, as far as water relations were concerned. Livingston (5) and Bakke (1) concluded that the cobalt chloride hygrometric paper measurements might be used as indices of a given plant's water relations. Bakke also believed that the indices determined offered a comparatively simple and adequate method for classifying plant forms in a scale of xerophytism or mesophytism. Pool (8) studied forty representative species found in various plant communities from the short-grass mesas and plateaus east of Colorado Springs and up through the foothill bushlands to the subalpine forest associations, and the alpine meadows above an altitude of 12,000 feet. He determined the indices of "transpiring power," beginning with the most xerophytic forms and closing with the more mesophytic. In addition he made an anatomical study of the leaves of representative species and found that some species with strikingly xeromorphic leaves showed relatively high indices of "transpiring power." The indices for dominants and other species of various communities did not show very satisfactory differentiation of habitats. Wilson (12), working upon transplanted plants, found that the so-called xerophytes of Australia, "so long as the available water supply is adequate, have no special powers of accommodation," as far as transpiration is concerned. Meyer (7) studied eight woody species in Ohio and states "it is doubtful if the standard rate of water-vapor loss from the leaves of a species may be taken as an adequate criterion of the relative mesophytism or xerophytism of that species."

It will be noted that the data to be presented were obtained in habitats of entirely different plant formations from those studied by Livingston (5), Bakke (1) and Pool (8), but in the same as those of Meyer. Instead of isolated measurements

made on each plant as those of Livingston, Bakke and Pool and attempts at correlation with the habitat, these data represent a series of measurements made on each plant, at hourly intervals during a considerable part of the daylight period. It was expected that the more complete measurements would be more likely to show whether or not a correlation between habitat and rate of water-vapor loss existed.

It should be emphasized again that it is not likely that accurate comparisons of relative transpiration rates are possible between the plants growing on a dry, exposed hilltop and plants growing in a very moist habitat; or between herbaceous plants on the forest floor and exposed leaves of the tree cover. However, the standard water-vapor loss of plants of the two situations can be accurately compared.

In all cases the species selected for the tests are fairly representative of the given association. Leaves were selected which were apparently of the same age, size and condition. For each species, tests were made on five different leaves and the results averaged. Thus each figure on the following graphs represents the average of five approximately simultaneous measurements. The temperature was standardized to 20° C. for all the tests by Livingston and Shreve's (6) method. The standard water-vapor loss is given in terms of grams or fractions thereof, on the ordinates. The time representing daylight hours is shown on the abscissae.[3] The legend accompanying the graphs denotes the association in which the plants were growing, the date upon which the measurements were made, and the name of the plant. Usually two species were measured during a given day. These two were growing close together and living under very similar environmental conditions, except where type of root systems varied. Graphs for these may be identified by the dates given, if comparisons are desired. The nomenclature used is that of Gray (4).

An analysis of the data presented shows that in practically all species where no stomata are present on the upper surface of the leaves, the cuticular loss is 0.3 gram or less per hundred square centimeters of leaf surface per hour. This value is approximately the same whether the plant is growing in a dry habitat such as Oak-Cedar Cliffs association, in a Chestnut-

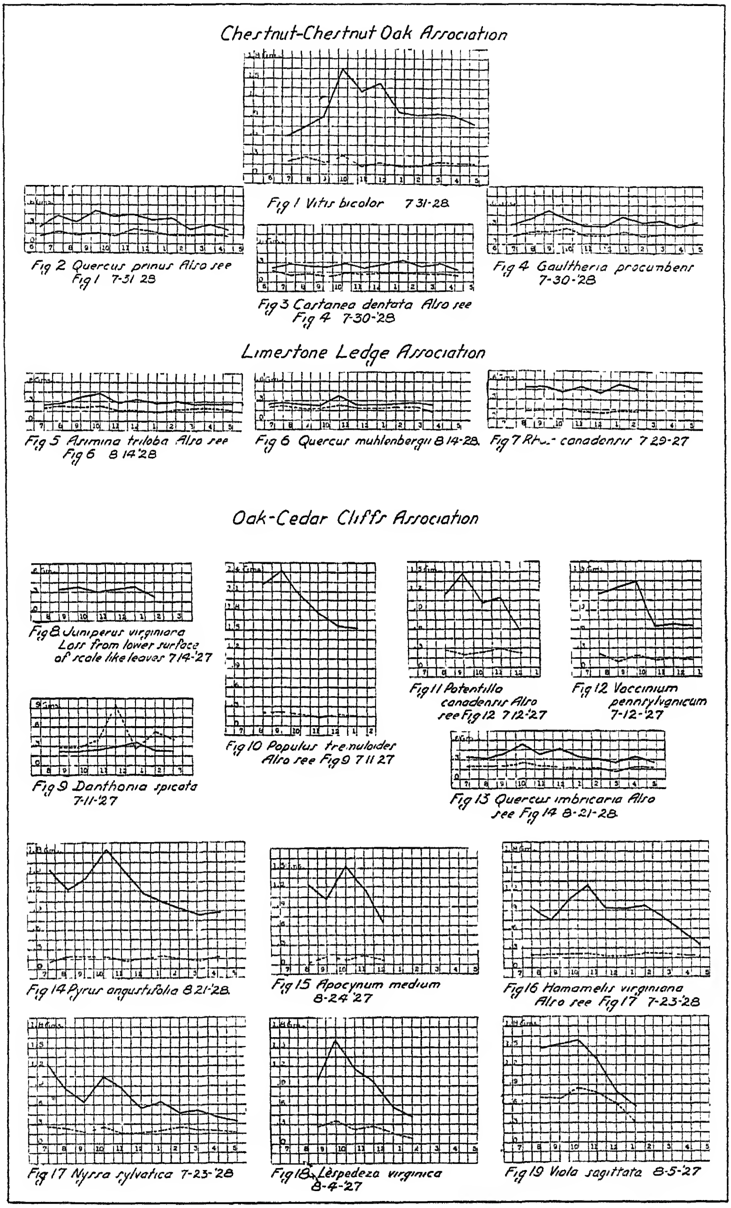
[3]Dotted lines of graphs (Figs. 1–119) indicate water vapor-loss from upper leaf surfaces, and solid lines loss from lower surfaces.

Chestnut Oak habitat, in a moist situation such as Buttonbush Swamp, or on a Sandbar.[4]

In the most xeric habitats studied, namely, the Chestnut-Chestnut Oak and the Limestone Ledge associations, the water-vapor loss from the surfaces bearing stomata was but little greater than stomata free surfaces. A decided exception is *Vitis bicolor* (Fig. 1), which was growing very near *Quercus prinus* (Fig. 2). *V. bicolor* is characteristic of the Chestnut-Chestnut Oak situation in Ohio. The measurements on the two plants were taken almost simultaneously (half hour apart). The water-vapor loss of the *V. bicolor* had a much greater maximum (1.7 g.), and in general, the whole water loss curve is greater than that of *Vitis cordifolia* (maximum, 1.1 g.) (Fig. 86), a typical River Bank form. Incidentally, a comparison of these two is also of interest since the leaves of *V. bicolor* are quite hairy while those of *V. cordifolia* are glabrous. This again emphasizes the fact that epidermal hairs are of no importance in retarding water-vapor loss, agreeing with Sayre's results for *Verbascum* (9). A comparison between the water losses of these two species of grape also indicates that a species typical of a dry habitat may lose water-vapor more rapidly than a typical species of a constantly moist habitat. Possibly internal conditions are of greater importance in determining the type of water loss than the amount of available water in the soil.

In the Oak-Cedar Cliffs association some comparatively high water losses are recorded. This particular region is underlaid with Ohio Black Shale from which considerable seepage occurs in deep ravines most of the year. *Populus tremuloides* (Fig. 10) showed an exceptionally high rate of water-vapor loss. *Quercus imbricaria* (Fig. 13) showed a very low rate. *Pyrus angustifolia* (Fig. 14) growing within a few feet of the oak was measured during alternate hours on the same day. A comparatively high rate of water loss was shown. *Danthonia spicata* (Fig. 9) is of interest since the greater loss is from the upper surface of the leaves. Loss from the lower surface is more nearly that found for cuticular surfaces. This species with *Juniperus* (Fig. 8) and *Quercus*, had the lowest rates of water-vapor loss among the twelve species studied. It is of

[4]For some associations, habitat names rather than standard plant association names have been used in order to indicate more specifically conditions in which the particular experimental plants were growing.



Chestnut-Chestnut Oak Association

Fig 1 Vitis bicolor 7 31-28

Fig 2 Quercus prinus Also see Fig 1 7-31 28

Fig 3 Castanea dentata Also see Fig 4 7-30-28

Fig 4 Gaultheria procumbens 7-30-'28

Limestone Ledge Association

Fig 5 Asimina triloba Also see Fig 6 8 14 28

Fig 6 Quercus muhlenbergii 8 14-28

Fig 7 Rh[illegible] canadensis 7 29-27

Oak-Cedar Cliffs Association

Fig 8 Juniperus virginiana Loss from lower surface of scale like leaves 7 14-'27

Fig 9 Danthonia spicata 7-11-'27

Fig 10 Populus tremuloides Also see Fig 9 7 11 27

Fig 11 Potentilla canadensis Also see Fig 12 7 12-'27

Fig 12 Vaccinium pennsylvanicum 7-12-'27

Fig 13 Quercus imbricaria Also see Fig 14 8-21-28

Fig 14 Pyrus angustifolia 8 21-28

Fig 15 Apocynum medium 8-24-'27

Fig 16 Hamamelis virginiana Also see Fig 17 7-23-'28

Fig 17 Nyssa sylvatica 7-23-'28

Fig 18 Lespedeza virginica 8-4-'27

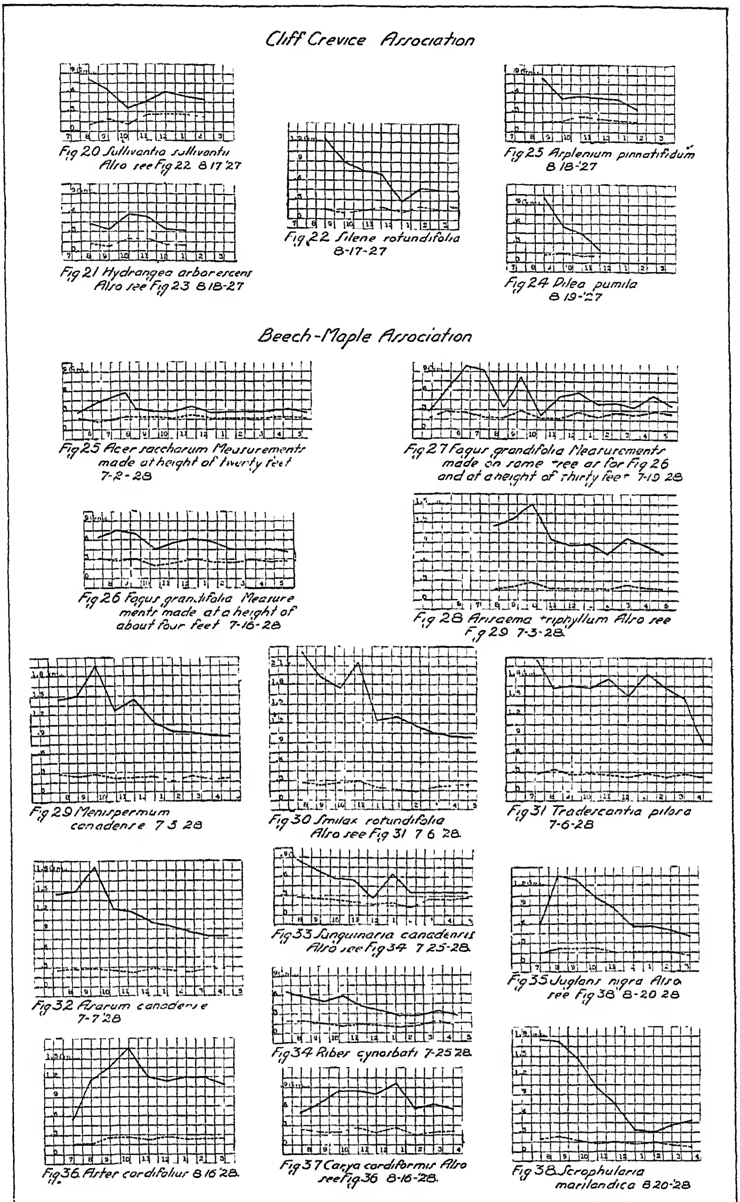
Fig 19 Viola sagittata 8-5-'27

interest to compare the loss from *Danthonia* with that of *Viola* (Fig. 19). These two plants grew side by side, and both are shallow-rooted forms.

The Cliff Crevice association types showed no great extremes of water-vapor loss. It is probable that such forms experience at least short extreme droughts due to the small accumulations of soil. Probably all species have been eliminated excepting forms which can withstand such dry periods.

Acer saccharum (Fig. 25), one of the dominants of the Beech-Maple habitat, showed a loss which might have been expected in a more xeric situation; in fact the curve is very similar to *Castanea* (Fig. 3), *Gaultheria* (Fig. 4), and *Quercus prinus* (Fig. 2), of the Chestnut-Chestnut Oak association. The similarity of the curves for *Asimina triloba* (Fig. 5), *Quercus muhlenbergii* (Fig. 6), and *Rhus canadensis* (Fig. 7), of the Limestone Ledge association, which was very dry, is also quite apparent. On the other hand, *Tradescantia pilosa* (Fig. 31) and *Smilax rotundifolia* (Fig. 30), of the Beech-Maple habitat, were in the group of highest water-vapor losing species found. *Ribes cynosbati* (Fig. 34), growing within a few feet of the others, showed a low rate of loss, approaching that of *Acer*. *Arisaema* (Fig. 28) and *Asarum* (Fig. 32) showed a water-loss curve which falls between the high and low water losers of the habitat. The graphs for these two are also strikingly similar. The loss curve for *Sanguinaria* (Fig. 33) is of interest in comparison to these last two since it is an herbaceous, early spring form and approaches *Acer* and *Ribes* in its type of water loss. The habitat of these Beech-Maple forms was very moist at the time measurements were made, due to a preceding thirty day period during which time rain fell almost every day. *Scrophularia* (Fig. 38), *Juglans* (Fig. 35), and *Aster* (Fig. 36), were growing in a more open place within the Beech-Maple habitat. Measurements on these species were made during a much drier period. These three showed water-loss curves having well marked periodicity with the maxima during the morning hours.

The Beech Forest association is very similar to the Beech-Maple community. Poorer drainage, probably, is the condition which eliminates the maples. Excepting *Fagus* (Fig. 41), all the species measured in this situation were forms not tested in the Beech-Maple situation. In general, the loss curves are similar to those of the related community. Growing within



Cliff Crevice Association

Fig 20 Sullivantia sullivantii Also see Fig 22 8 17 '27

Fig 21 Hydrangea arborescens Also see Fig 23 8-18-27

Fig 22 Silene rotundifolia 8-17-27

Fig 23 Asplenium pinnatifidum 8-18-'27

Fig 24 Pilea pumila 8-19-'27

Beech-Maple Association

Fig 25 Acer saccharum Measurements made at height of twenty feet 7-2-28

Fig 26 Fagus grandifolia Measurements made at a height of about four feet 7-16-28

Fig 27 Fagus grandifolia Measurements made on same tree as for Fig 26 and at a height of thirty feet 7-19 28

Fig 28 Arisaema triphyllum Also see Fig 29 7-3-28

Fig 29 Menispermum canadense 7 3 28

Fig 30 Smilax rotundifolia Also see Fig 31 7 6 28

Fig 31 Tradescantia pilosa 7-6-28

Fig 32 Asarum canadense 7-7 28

Fig 33 Sanguinaria canadensis Also see Fig 34 7 25-28

Fig 34 Ribes cynosbati 7-25 28

Fig 35 Juglans nigra Also see Fig 38 8-20 28

Fig 36 Aster cordifolius 8 16 28

Fig 37 Carya cordiformis Also see Fig 36 8-16-28

Fig 38 Scrophularia marilandica 8 20 28

a few feet of each other, the curves for *Fagus* and *Cornus* (Fig. 42) are similar. However, the maxima are rather widely separated. The curves for *Circaea* (Fig. 39) and *Actea* (Fig. 40) which grew side by side are also paralleled.

Among the species studied in a transition between Swamp Forest and Beech-Maple no unusual departures were found except among the Oaks. *Quercus alba* (Fig. 53) and *Q. rubra* (*borealis*) (Fig. 52) showed high maxima in the early morning. This did not appear previously in the species of *Quercus* from apparently drier habitats.

Species of the Swamp Forest habitat show a wide range of variation in rates of water loss. The highest loss observed (2.9 g. per sq. dm.) during this investigation was that recorded for *Lobelia cardinalis* (Fig. 62). *Quercus macrocarpa* (Fig. 56) and *Q. bicolor* (Fig. 55) showed water loss curves which were quite similar to oaks of more xeric habitats. *Quercus palustris* (Fig. 63) approaches the average for this association.

Graphs of several of the Flood Plain species are short due to a very rainy season, and to nights with low temperatures and heavy dews. This prevented the early morning measurements. *Fraxinus americana* (Fig. 68) and *Prunus serotina* (Fig. 69), growing side by side, with the measurements taken upon alternate hours, show similar curves, and *Pilea pumila* (Fig. 65) compared with the same species growing in the Cliff Crevice association (Fig. 24) shows a higher and a later maximum

In the Mixed Mesophytic Forest, *Betula lenta* (Fig. 81) and *Cimicifuga racemosa* (Fig. 79) were the only species measured which showed a comparatively high water-vapor loss. The curve for *Fagus* (Fig. 83), *Oxydendron* (Fig. 80), *Kalmia* (Fig. 82), and *Rhododendron* (Fig. 78) approach those found commonly in drier situations. In south central Ohio, *Kalmia* is usually found on dry ridges. The water-vapor loss from it, however, is greater than from *Rhododendron*. Meyer (7) observed the same phenomenon. The time of greatest water loss for the *Rhododendron* occurred early in the morning, as previously reported by Meyer. *Kalmia* occurs abundantly on the very dry sandstone cliff-tops in southern Ohio, while *Rhododendron* is closely restricted to the moist ravines and north-facing slopes.

The River Bank forms show a rather wide range of fluctuations. They are more or less characterized by high, sudden maxima and rapid declines.

Beech Forest Association

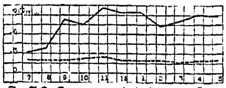


Fig 39 Circaea lutetiana Also see Fig 40 7-24-28

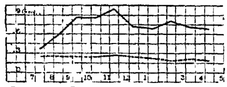


Fig 40 Actaea alba 7-24-28

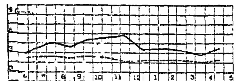


Fig 41 Fagus grandifolia Also see Fig 42 7-20 28.

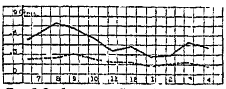


Fig 42 Cornus florida 7 20 28

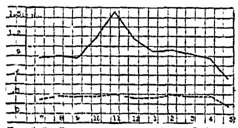


Fig 44 Eupatorium urticaefolium villicaule 8-6 28

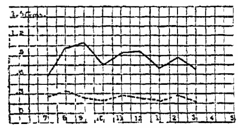


Fig 45 Evonymus obovatus Also see Fig 46 7-26-28.

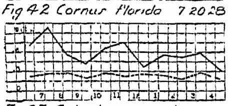


Fig 43 Celastrus scandens Also see Fig 44 8-6-28

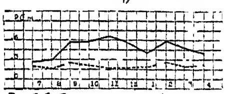


Fig 46 Carpinus caroliniana 7 26-28

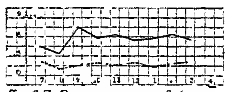


Fig 47 Panax quinquefolium Also see Fig 50 7-20 28.

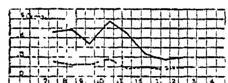


Fig 48 Polygonatum biflorum 7-20-28

Transition from Swamp Forest to Beech Maple

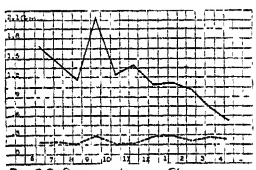


Fig 49 Rosa setigera Also see Fig 50 7 12-28

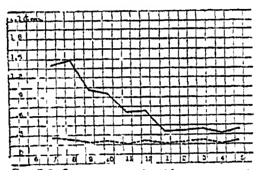


Fig 50 Carya ovata Measurements made at height of about four feet 7 12-28

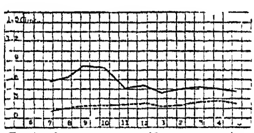


Fig 51 Carya ovata Measurements made at a height of twenty feet 7-11 28

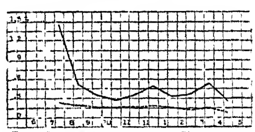


Fig 52 Quercus rubra Also see Fig 51 7-11 28

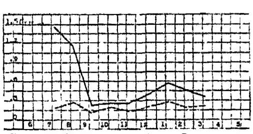


Fig 53 Quercus alba Also see Fig 54 7-13-28

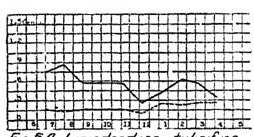
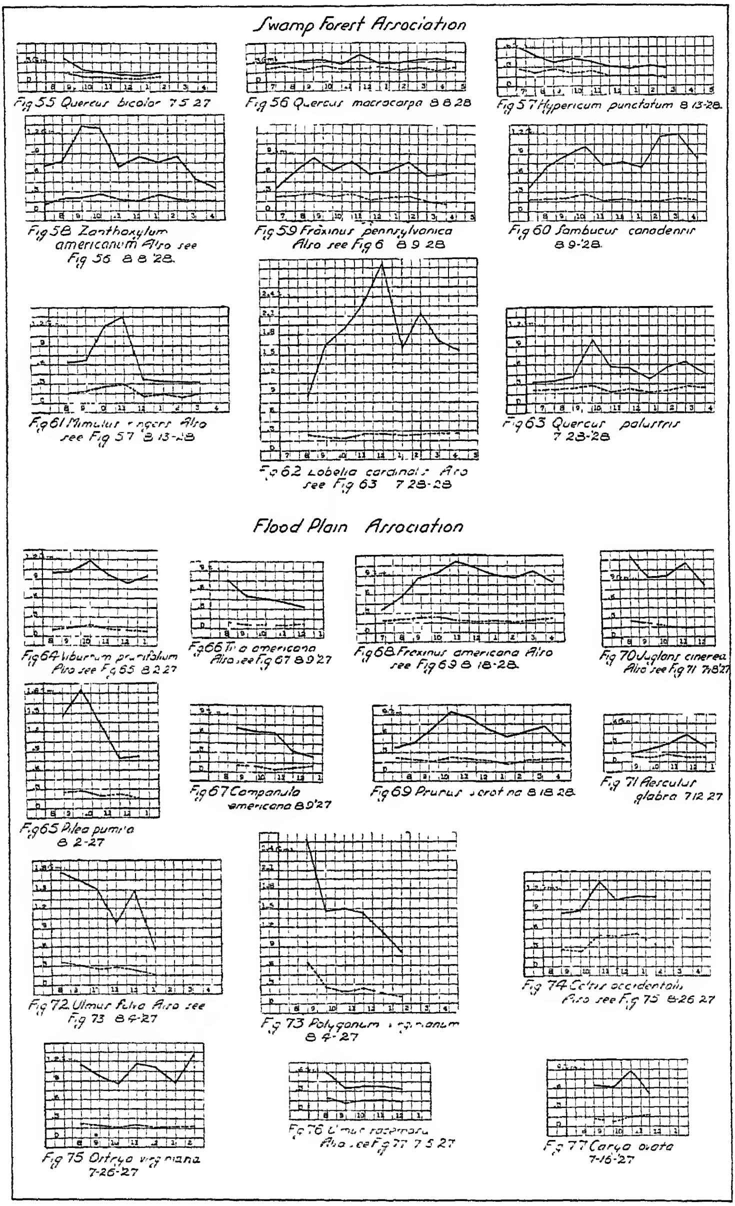
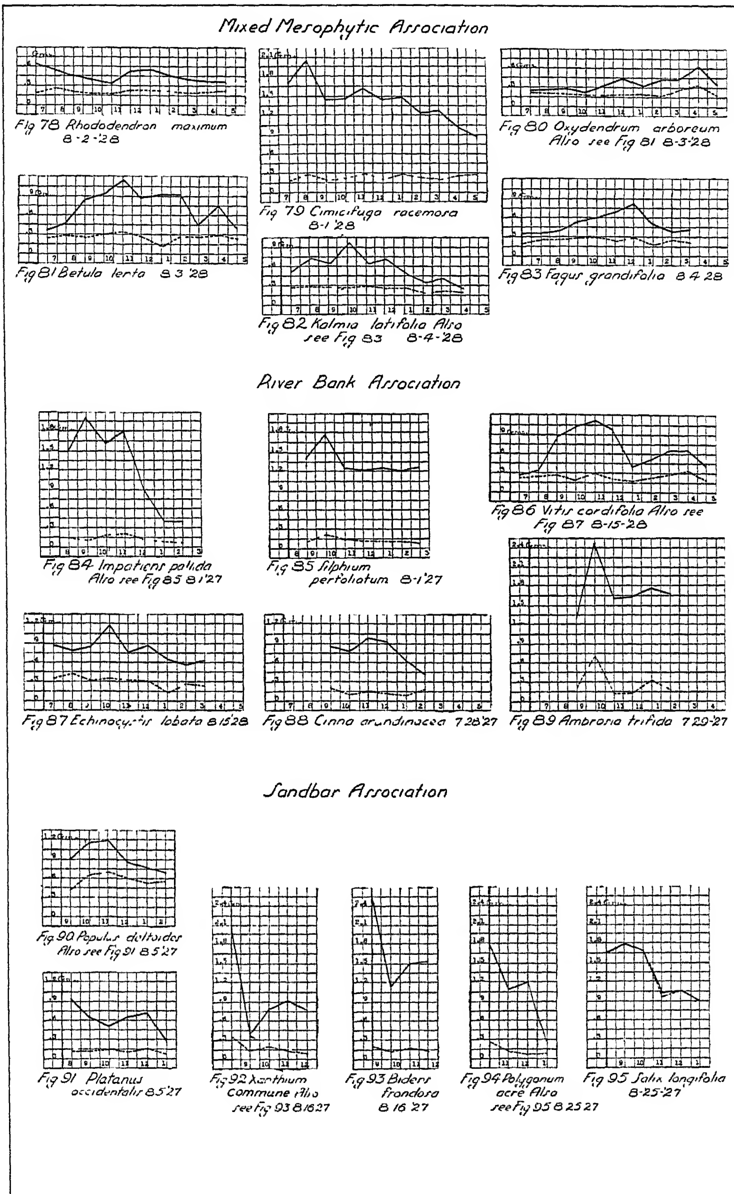


Fig 54 Liriodendron tulipifera 7-13 28


Swamp Forest Association
Fig 55 Quercus bicolor 7 5 27
Fig 56 Quercus macrocarpa 8 8 28
Fig 57 Hypericum punctatum 8 13-28
Fig 58 Zanthoxylum americanum Also see Fig 56 8 8 '28
Fig 59 Fraxinus pennsylvanica Also see Fig 6 8 9 28
Fig 60 Sambucus canadensis 8 9-'28
Fig 61 Mimulus ringens Also see Fig 57 8 13-28
Fig 62 Lobelia cardinalis Also see Fig 63 7 28-28
Fig 63 Quercus palustris 7 28-28
Flood Plain Association
Fig 64 Viburnum prunifolium Also see Fig 65 8 2 27
Fig 66 Tilia americana Also see Fig 67 8 9 27
Fig 68 Fraxinus americana Also see Fig 69 8 18-28
Fig 70 Juglans cinerea Also see Fig 71 7-18 27
Fig 65 Pilea pumila 8 2-27
Fig 67 Campanula americana 8 9'27
Fig 69 Prunus serotina 8 18 28
Fig 71 Aesculus glabra 7 12 27
Fig 72 Ulmus fulva Also see Fig 73 8 4-27
Fig 73 Polygonum virginianum 8 4-27
Fig 74 Celtis occidentalis Also see Fig 75 8-26 27
Fig 75 Ostrya virginiana 7-26-27
Fig 76 Ulmus racemosa Also see Fig 77 7 5 27
Fig 77 Carya ovata 7-16-27


Mixed Mesophytic Association
Fig 78 Rhododendron maximum 8-2-'28
Fig 79 Cimicifuga racemosa 8-1'28
Fig 80 Oxydendrum arboreum Also see Fig 81 8-3-'28
Fig 81 Betula lenta 8 3 '28
Fig 82 Kalmia latifolia Also see Fig 83 8-4-'28
Fig 83 Fagus grandifolia 8 4 28
River Bank Association
Fig 84 Impatiens pallida Also see Fig 85 8 1'27
Fig 85 Silphium perfoliatum 8-1'27
Fig 86 Vitis cordifolia Also see Fig 87 8-15-'28
Fig 87 Echinocystis lobata 8 15'28
Fig 88 Cinna arundinacea 7 28'27
Fig 89 Ambrosia trifida 7 29-'27
Sandbar Association
Fig 90 Populus deltoides Also see Fig 91 8 5'27
Fig 91 Platanus occidentalis 8 5'27
Fig 92 Xanthium commune Also see Fig 93 8 16'27
Fig 93 Bidens frondosa 8 16 '27
Fig 94 Polygonum acre Also see Fig 95 8 25 27
Fig 95 Salix longifolia 8-25-'27

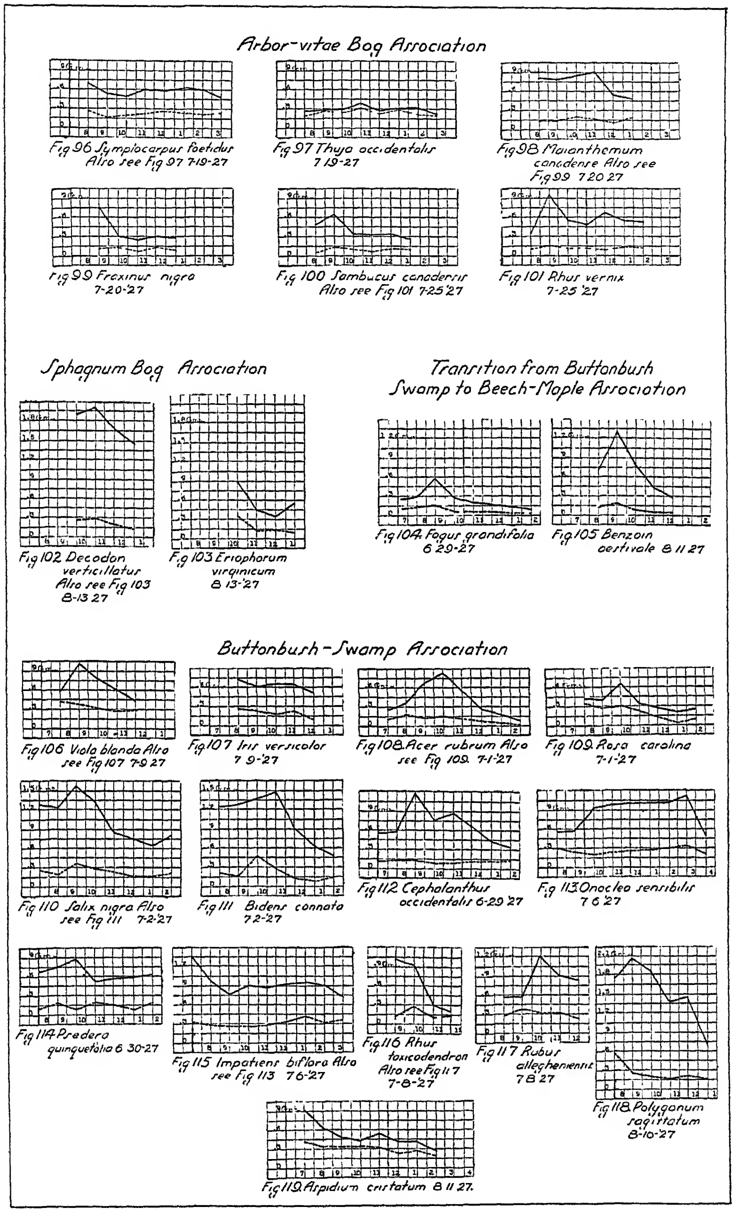
The Sandbar habitat species show high maxima at an early hour. Perhaps the graph for *Salix longifolia* (Fig. 95) is of some interest in that the losses from the two leaf surfaces are practically the same.

Representatives of the Arbor-vitae Bog association (alkaline) showed a relatively low rate of water-vapor loss. The curves for *Thuja* (Fig. 97) do not represent the upper and lower surfaces of the scale leaves, but the loss as measured from the upper and lower surfaces of the scale covered twigs. The soil is saturated with water in this situation practically the whole year. Root systems in such situations are usually poorly developed, due to lack of oxygen. This may account for the low rates obtained. Whitfield (11) concluded from his experiments with potted sunflowers that "Transpiration was found to be highest in soils of medium water content, next in saturated soils, and lowest in soils with low water content." *Sambucus* in this habitat (Fig. 100) has about half the rate of water loss of the same species (Fig. 60), growing in the Swamp Forest association.

Only two species of the Sphagnum Bog association (acid) were measured. The short curves are rather unsatisfactory, but do show two very different types of water-vapor loss: *Decodon*-high (Fig. 102), *Eriophorum*-low (Fig. 103).

The Buttonbush Swamp habitat is characterized by its saturated soil throughout the year. The water loss curves for the species in this situation are all low and much the same as in the Arbor-vitae Bog. One of the lowest was *Iris versicolor* (Fig. 107). It is common knowledge that this species grows well in much drier situations in cultivation. *Rosa carolina* (Fig. 109) showed the minimum water loss in the group. Its maximum was only .62 gram per unit area. Lack of available water cannot be the cause since the soil was saturated. *Fagus* (Fig. 104) and *Benzoin* (Fig. 105) represent the Transition Zone from Buttonbush Swamp to Beech-Maple; the first being low, the second, medium high.

The above analysis of the data presented indicates that the standard water-vapor loss of a species cannot be taken generally as an indicator of its xerophytic or mesophytic character. To make a separation on this basis would place many species of hydrophytic forms in xerophytic habitats where they rarely or never occur and *vice versa*. This indicates that the rate of standard water-vapor loss may be an important quality of the



Arbor-vitae Bog Association

Fig 96 Symplocarpus foetidus Also see Fig 97 7-19-27

Fig 97 Thuja occidentalis 7 19-27

Fig 98 Maianthemum canadense Also see Fig 99 7 20 27

Fig 99 Fraxinus nigra 7-20-27

Fig 100 Sambucus canadensis Also see Fig 101 7-25 27

Fig 101 Rhus vernix 7-25 27

Sphagnum Bog Association

Fig 102 Decodon verticillatus Also see Fig 103 8-13 27

Fig 103 Eriophorum virginicum 8 13-27

Transition from Buttonbush Swamp to Beech-Maple Association

Fig 104 Fagus grandifolia 6 29-27

Fig 105 Benzoin aestivale 8 11 27

Buttonbush-Swamp Association

Fig 106 Viola blanda Also see Fig 107 7-9 27

Fig 107 Iris versicolor 7 9-27

Fig 108 Acer rubrum Also see Fig 109 7-1-27

Fig 109 Rosa carolina 7-1-27

Fig 110 Salix nigra Also see Fig 111 7-2-27

Fig 111 Bidens connata 7 2-27

Fig 112 Cephalanthus occidentalis 6-29 27

Fig 113 Onoclea sensibilis 7 6 27

Fig 114 Psedera quinquefolia 6 30-27

Fig 115 Impatiens biflora Also see Fig 113 7 6-27

Fig 116 Rhus toxicodendron Also see Fig 117 7-8-27

Fig 117 Rubus alleghenensis 7 8 27

Fig 118 Polygonum sagittatum 8-10-27

Fig 119 Aspidium cristatum 8 11 27

plant in some cases and not in others, just as light intensity is important in the distribution of some species and not in others.

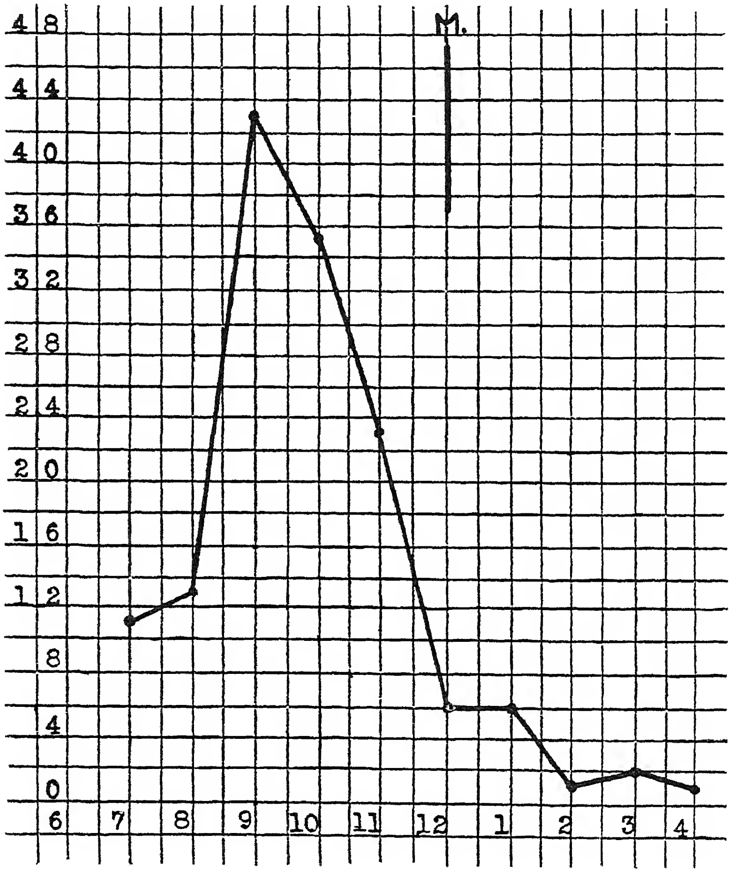


Fig 120

FIG. 120. This graph shows the frequency of the water-vapor loss maxima for nine hours of the daylight period, collected from 148 plants growing in various habitats. Over 93% of the maxima occurred between 7:00 A. M. and 12:00 M.; 89% occurred between 7:00 and 11:00 A. M.; 52% occurred from 9:00 to 10:00 A. M. The maxima are given on the ordinate and time on the abscissa.

Early maxima are outstanding characteristics of most of the water-vapor loss graphs presented. From these maxima a a frequency curve (Fig. 120) has been constructed for nine hours of the daylight period.[5] Data from thirty other water-

[5]In order to make this graph more uniform, measurements occurring on the half hour have been placed with those of the following hour. Those falling between the hour and half hour have been placed with the nearest hour.

vapor loss curves, which have not been used otherwise in this paper, are included in this particular compilation. Plants from which these curves were made were cultivated varieties, weeds and additional wild forms used in investigating other water-vapor loss phenomena. Table I gives a list of these plants along with their time of maximum loss.

TABLE I

Name	Time of Maximum Water-Vapor Loss.
Asclepias syrica	11 00 A. M.
Canna flaccida	10 00 "
Growing in the greenhouse.	
Cannabis sativa	9:00 "
Bologna variety, staminate plant.	
Cannabis sativa	9.00 "
Bologna variety, carpellate plant.	
Cannabis sativa	10.00 "
Chington variety, staminate plant.	
Cannabis sativa	10 00 "
Chington variety, carpellate plant.	
Cannabis sativa	9 00 "
Commercial variety, staminate plant.	
Cannabis sativa	9.00 "
Commercial variety, carpellate plant.	
Cannabis sativa	9:00 "
Simple Leaf variety, staminate plant.	
Cannabis sativa	9.00 "
Simple Leaf variety, carpellate plant.	
Carica papaya	9:00 "
Growing in greenhouse.	
Commandra umbellata	9:00 "
Conocephalum conicum	10:00 "
Gametophyte.	
Diospyros virginiana	8:00 "
Measurements made July 10th.	
Diospyros virginiana	9:00 "
Same plant as above, but measured September 18th.	
Fraxinus caroliniana	11:00 "
Gossipium herbaceum	11:00 "
Melbane Big Bole Early Triumph.	
Helianthus tuberosus	10:00 "
Potted plant.	
Phaseolus vulgaris	1:00 P. M.
Measured August 20th.	
Phaseolus vulgaris	10:00 A. M.
Not the same as above. Measured August 16th.	
Phaseolus vulgaris	11:00 "
Seedling, measured September 3rd.	
Phaseolus vulgaris	10:00 "
Seedling, measured August 27th.	
Phoradendron flavescens.	1:00 P. M.
Pyrus malus	9:00 A. M.
Grimes Golden variety. Measured July 10th.	
Pyrus malus	9:00 "
Same plant as above, but measured September 18th.	
Rhododendron maximum.	12:00 M.
Leaves of second season.	
Sicyos angulatus	9:00 A. M.
Vaccinium pennsylvanicum	10:00 "

An analysis of this frequency curve of the water-vapor loss maxima determined for plants growing under various conditions, shows the percentage of maxima occurring between 7:00 A. M. to 12 M. to be over 93%; over 89% occurred between 7:00 to 11:00 A. M.; and 52% between 9:00 and 10:00 A. M. The greatest number of maxima (29%) occurred at 9:00 A. M. In other words, for over 93% of the plants studied, water-vapor loss maxima occurred before the period of maximum evaporation. An analysis of the maxima for each plant association shows that they are all quite variable within a given habitat, but that a majority in each location occurred before noon.

In practically all species studied, a distinct rhythm in the rate of water-vapor loss was very apparent. In some species the cuticular loss from the upper, stomata-free surfaces, showed slight rhythms.

It will be noted that measurements were made on *Fagus* (Figs. 27, 41, 83, 104) growing in four different habitats; *Sambucus* (Figs. 60, 100), *Carya ovata* (Figs. 50, 77), and *Pilea* (Figs. 24, 65), each growing in two different associations. As shown in these figures, the time of the maximum water-vapor loss, as well as the rhythms in general, varied from place to place.

Graphs are also presented showing the standard water-vapor loss from two different positions in the same tree. The species used were *Fagus* (Figs. 26, 27) and *Carya ovata* (Figs. 50, 51). The beech was measured at a height of thirty feet and again at approximately four feet. The lower position showed a higher maximum loss and a more pronounced rhythm. Measurements were made on the hickory at a height of twenty feet, and again at about four feet. The lower position showed a much higher maximum and, in general, a greater water-vapor loss.

SUMMARY

1. Determinations have been made of the standard water-vapor loss rates for 148 species of plants, representative of 16 plant associations located in the Deciduous Forest Formation of Ohio and Indiana.

2. Measurements were made, usually at hourly intervals, several times during the daylight period. This made possible the construction of curves showing diurnal variations in rate of water-vapor loss. This enables one to gain a more accurate idea of total daily standard water-vapor loss and its relation, if any,

to the habitat. Most other investigators of water loss have confined their determinations to isolated measurements. In many species the graphs show that the time of day may make a difference of 100% or more.

3. The standard water-vapor loss from herbaceous and low shrubs of the forest floor is often greater than the loss from lower leaves of plants forming the canopy. This conclusion is based upon comparisons of the loss of the forest floor types and the lower leaves of the canopy-forming trees. The atmospheric conditions about the lower leaves (three to five feet from the ground) and the herbaceous and low shrubby plants are probably not different.

4. This investigation indicates that the standard water-vapor loss of a species is not necessarily correlated with the position of a species in a relative scale of xerophytism, as indicated by the usual habitat of that species. Many xerophytic species exhibit relatively high rates of water-vapor loss, while *vice versa*, many mesophytic species have low rates.

5. Evidence is presented which indicates that plants growing in soil saturated with water and poorly aerated, such as in bogs and swamps, have lower rates of water-vapor loss than many growing in drier habitats, often approaching those of xeric situations. Internal physiological conditions and poorly developed root systems may be the causes.

6. For most species the time of maximum water-vapor loss occurs during the morning hours, long before the time of maximum evaporation. A frequency curve, constructed from these maxima, shows that 93% of the 148 plants studied, have their maximal water-vapor loss between 7:00 A. M. and 12 M., over 89% between 7:00 and 11:00 A. M., and 52% between 9:00 and 10:00 A. M. The greatest number of maxima occurred about 9:00 A. M., regardless of whether the habitats were wet or dry.

7. Pronounced periodicity of water-vapor loss occurred from the stomatal surfaces of nearly all species.

8. The majority of plants investigated showed a water-vapor loss of 0.3 g. per sq. dm. of leaf surfaces free of stomata.

9. When the same species was studied in two or more habitats the rate and the curves were usually different.

10. The lower leaves of *Fagus* and *Carya* had greater water-vapor loss than those at higher levels.

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Geologic Structures

In 1923 Bailey Willis wrote the first edition of "Geologic Structures" and used some 295 pages to describe them and to interpret them. The second edition appeared in 1929 and a third revised edition in 1934. This last edition gives within useful limits a complete treatment of the subject. In sixteen chapters and four appendixes the two authors consider geologic structure. The chapters in order take up Problems of Rock Deformation, *Mechanical Principles*, Stratified Rocks, Flexures and Folds, *Analysis of Folds*, Division of Rocks by Joints, Description of Faults, *Fault Types and Fault Displacements*, *Analysis of Faulting*, Structures of Igneous rocks. Structures of Metamorphic rocks, Physiographic Expression of Structure, Field Methods, *Graphic Methods*, *Practical Problems*, and Fundamental Facts and Concepts. The headings in italics are more technical than the others. The appendices are mainly technical discussions of various aspects of structure or experimental work on folds.

Students of geology will find considerable food for thought contained in the 509 pages. For those not primarily interested in structure it is an excellent hand book. Essentially it is a textbook for systematic study of structure.

—Willard Berry.

Geologic Structures, by Bailey Willis and Robin Willis. xviii+544 pp. New York, McGraw-Hill Book Co., 1934. $4.00.

THE ALIMENTARY CANAL OF *HARPALUS PENNSYLVANICUS* DEJ. (CARABIDAE: COLEOPTERA)

F. B. WHITTINGTON
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During the latter part of September, 1932, a species of Carabidae, *Harpalus pennsylvanicus* Dej., was found in large numbers about one mile west of Worthington, Ohio. The insect was most common under small batches of hay in an alfalfa field. About fifty specimens were collected and taken to the laboratory for use in a morphological study of the alimentary canal. Half of the specimens were immediately killed and fixed in Kahle's (Dietrich's) fixative. After thorough washing, these insects were then stored in 70 per cent alcohol for future use. The remaining twenty-five specimens were placed in a small screen cage about two feet square and covered with leaves at the base of a large sycamore tree. This procedure permitted the use of live specimens during the entire winter.

The figures herein presented were reproduced from material stained with Haemalum and Fast Green. This combination served very well to differentiate the cell layers and the nuclei, but in some sections the cell walls were not distinct. Delafield's haematoxylin and eosin were tried in various combinations but with results often less satisfactory.

This work was done at the Ohio State University under the supervision of Dr. Clarence H. Kennedy, to whom the writer is grateful for advice and criticism during the course of study.

GENERAL DESCRIPTION OF THE ADULT

The beetle is an oblong, robust species varying in length from 13–15.5 mm. The back is uniformly black and moderately shiny while the lower surface is dark reddish brown to piecious. The antennae are reddish yellow. The thorax is broader than long, with the base as wide as the elytra.

THE ALIMENTARY CANAL

The total length of the canal is approximately 21.5 mm. The cellular structure indicates that it is divided into three main divisions. The anterior portion, *fore-gut*, and the posterior portion, *hind-gut*, are continuations of the body wall. These two divisions are connected by a

central division, *mid-gut*, which is entirely different in cellular structure. The exact location of the main divisions and the subdivisions of the alimentary canal depends largely on the amount of food an individual has taken and the amount of adipose tissue in the body. In general, however, the fore-gut is approximately 8.5 mm. in length and occupies the position shown in Fig. 1, extending along the ventral part of the body to the first abdominal segment. The mid-gut, averaging 6.5 mm. in length, begins at the oesophageal valve and joins the hind-gut in the posterior half of the third abdominal segment. The hind-gut is approximately 6.5 mm. long, extending from the Malpighian tubules to the anal opening.

FORE–GUT

The fore-gut, measuring 8.5 mm., consists of the *buccal cavity*, *pharynx*, *oesophagus*, *crop*, *provintriculus*, and *oesophageal valve.* This division begins with the buccal cavity at the anterior end and extends to the oesophageal valve at the posterior end. The pharynx is very small and short, measuring less than .4 mm. in length. The oesophagus is approximately 4.5 mm. long, extending from the pharynx posteriorily to the crop. At this point the canal enlarges to form a bulb-like organ, the crop, which is about 3 mm. long and in most specimens occupies a position in the hind part of the metathorax and first abdominal segment. At the posterior end and somewhat from the side of the crop the provintriculus connects the crop to the mid-gut. The provintriculus is .5 mm. in length and is hardly distinguishable except by cellular structure.

In general the histological structure of the fore-gut is similar to that of the body wall. A cross-section of this part of the canal shows the following cellular layers: (1) a chitinous inner lining, *intima;* (2) an *epithelium* of hypodermal cells; (3) a layer of *longitudinal muscles;* (4) a layer of *circular muscles*, and (5) an inclosing membrane of *connective tissue* (*Peritoneum* with some writers). This arrangement of the cellular layers is continuous in the fore-gut, but in some sub-divisions a layer may be more pronounced than in others.

The intima or chitinous lining of the digestive cavity is distinct through the fore-gut. Figs. 2 and 5 show that in the oesophagus it is comparatively thin while in the provintriculus the layer is much heavier and is densely covered with spine-like projections. The large longitudinal folds are provided with secondary folds having serrated margins.

Epithelium is present in each of the subdivisions. In the oesophagus, however, the cells are hardly visible at a magnification of 440 times, while in the provintriculus they are outstanding under such magnification.

The longitudinal muscles of the fore-gut are in longitudinal folds which vary in number along the oesophagus. In the provintriculus they are definitely arranged into four distinct folds, the surface of which comprises approximately one-half the lining of the provintriculus.

The circular muscles vary from a few scattered strands around the walls of the oesophagus to a layer several cells in thickness in the provintriculus. The heavy layers of longitudinal and circular muscles in the provintriculus indicate that it is a powerful organ in the process of digestion even though it is relatively small.

A layer of connective tissue surrounds the fore-gut. In many cases this tissue is torn from the wall of the digestive tract in the process of sectioning.

The oesophageal valve, Fig. 6, marks the posterior end of the fore-gut. This valve consists of a heavy circular fold of the epithelium which extends slightly into the anterior end of the mid-gut. It is richly supplied with circular and longitudinal muscles, the position of which, in relation to the fore-gut, is completely reversed in this part of the canal.

MID-GUT

The mid-gut extends from the oesophageal valve at the anterior end to the pyloric valve at the posterior end. When in its natural position it is spiral shaped with the posterior end near the center of the body. It is approximately 6.5 mm. long and is divided into two slightly different parts, the *anterior mid-gut,* which is 1 mm. in length, and the *posterior mid-gut,* which measures 5.5 mm. This division of the canal is densely covered with *crypts* which are all uniformly perpendicular to the walls of the gut. Fig. 1 shows the uniformity which is expressed at the expense of the perpendicular arrangement. On the surface of the anterior mid-gut, the crypts are much larger than those on the posterior mid-gut.

There are four layers of cells in the mid-gut arranged in the following order, beginning with the lining of the digestive cavity (Fig. 4): (1) epithelial cells, (2) circular muscles, (3) longitudinal muscles, and (4) connective tissue. The epithelial layer is distinct and is locally crowded into folds between the bases of which it is evaginated into crypts that cover the surface of the mid-gut. This arrangement of cells greatly increases the surface of the epithelium in this division of the canal. The cells of this layer vary from a rectangular form in uncrowded conditions to a long club-shaped form where the cells are more congested.

Circular muscles of the mid-gut vary in thickness from one to three cells, and compared with circular muscles of other parts of the intestine, they are exceedingly minute.

The longitudinal muscles do not form a continuous layer around the mid-gut. Muscle strands that are present are often barely visible when magnified 950 times.

A thin layer of connective tissue surrounds the mid-gut (Fig. 4).

The crypts which cover the surface of the stomach are composed of large distinct cells which are continuous with the epithelium of the mid-gut. At the tip of the crypts are located the nidi which, according to Comstock, are areas of cell reproduction and rapid growth (Fig. 10).

HIND-GUT

The hind-gut is 6.5 mm. in length and consists of the *pyloric valve, Malpighian tubules, ileum* and *rectum.* The anterior end is marked by the entrance of the Malpighian tubules. The four tubules enter the digestive tract separately, but when viewed from the exterior they appear to enter in pairs. They are approximately the same length as the digestive tract and are thoroughly woven into the tracheae and

fatty tissue that surround the walls of the mid-gut. The ileum is 4.5 mm. in length and is comparatively uniform in size to a point near the junction of the rectum, where the size is doubled. The rectum is cone-shaped, tapering to about .3 mm. in diameter at the anal opening. The six rectal pads are located near the anterior end and are plainly visible through the transparent walls of the intestine (Fig. 1).

Beginning with the lining of the digestive cavity the cell layers appear in the following order: (1) intima, (2) epithelium, (3) longitudinal muscles, (4) circular muscles, (5) longitudinal muscles, and (6) connective tissue.

The pyloric valve is formed by a circular arrangement of enlarged areas of epithelium of the hind intestine (Figs. 7 and 8). Between these areas the malpighian tubules make their entrance to the digestive tract.

When viewed in cross-section the Malpighian tubules consist of a cellular layer varying from a large number of small cells at the open end to about ten large cells at a more distal point. The inner lining of the tubules is composed of *pore canals* which give this tissue a striated appearance when viewed in cross-section (Fig. 11). The large cells are surrounded by an inclosing layer of connective tissue which contains an occasional large cell which, it is believed, may serve as circular muscle.

The intima is evident throughout the hind intestine and is about equal in thickness in each subdivision.

The epithelium is continuous in the hind intestine. In the ileum it surrounds the large groups of longitudinal muscles. It varies in thickness along the tract, and in the rectal pads the layer is composed of two types of cells, the large rectangular cells of the pads and the normal epithelial cells at their base.

The longitudinal muscles are in two layers which are separated by circular muscles. The layer adjacent to the epithelium is grouped into six large folds of epithelial tissue. The second layer of longitudinal muscles is also in groups and is immediately surrounded by the connective tissue (Fig. 12).

The circular muscles are large and numerous in the ileum, while near the rectal pads the layer is reduced to scattered large cells.

The hind intestine is surrounded by a layer of very thin connective tissue (Figs. 7 and 12).

At the anterior end of the rectum the walls approach a transparent condition. As a result of this condition the rectal pads are subject to examination from the exterior. In an alternating arrangement three of these pads are more anteriorly placed than are the other three (Fig. 1).

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EXPLANATION OF PLATES

Plate I

Fig 1. Dorsal view of alimentary canal arranged to show the relative proportion and position of the parts. (× 10.)

Fig. 2. Cross-section of the oesophagus.

Fig. 3. A part of the same section as Fig. 2 when under much greater magnification.

Fig 4 Cross-section of the posterior mid-gut. Note crowded condition of the epithelium and presence of folds.

Plate II

Fig. 5. Cross-section of the provintriculus. Note the heavy chitinous intima and spine-like projections.

Fig. 6 Longitudinal section of the provintriculus and oesophageal valve. Note change in position of muscle layers.

Fig. 7. Longitudinal section of the pyloric valve and part of ileum. Note change in position of muscle layers at valve. Two layers of longitudinal muscle are present in the ileum, but this section illustrates only one.

Fig. 8. Cross-section of the pyloric valve showing the entrance of the Malpighian tubules.

Plate III

Fig. 9. Cross-section of the rectum showing the rectal pads.

Fig. 10. Longitudinal section of a crypt showing the nidus and globules of secretion.

Fig. 11. Cross-section of the Malpighian tubule near distal end.

Fig. 12. Cross-section of the ileum. Note the heavy layer of circular muscles and the two layers of longitudinal muscles.

SYMBOLS USED IN PLATES

A. M.—Anterior mid-gut
C. M.—Circular muscle
CR.—Crypt
C. TIS.—Connective tissue
EPITH.—Epithelium
EPITH. C.—Epithelial cells
IN.—Intima
L. MUS.—Longitudinal muscle
LU.—Lumen of intestine
M. TUB.—Malpighian tubule
OES.—Oesophagus
O. V.—Oesophageal valve
PROV.—Provintriculus
P. M. GUT—Posterior mid-gut
P. CANAL—Pore canal
P. V.—Pyloric valve
REC.—Rectum
REC. PAD—Rectal pad
SEC.—Secretion of crypt

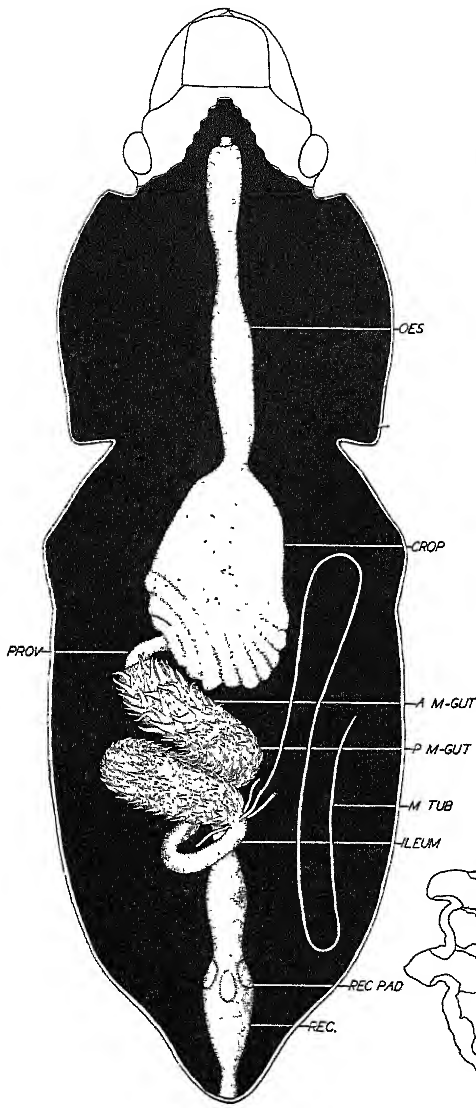

FIG 1

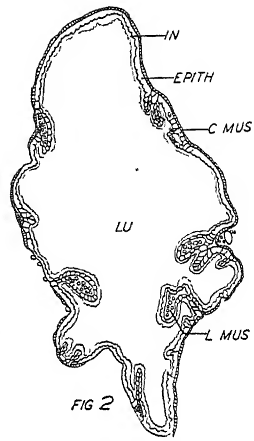

FIG 2

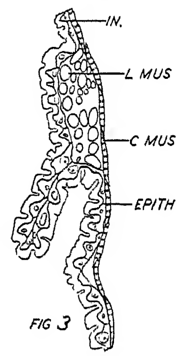

FIG 3

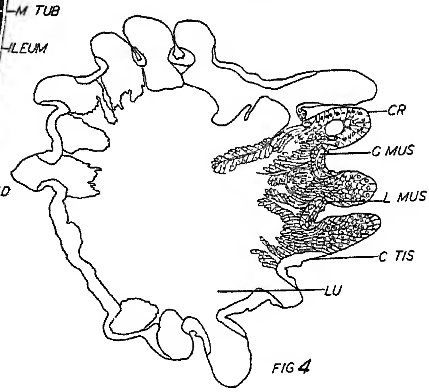

FIG 4

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LORAIN, OHIO: A STUDY IN URBAN GEOGRAPHY*

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INTRODUCTION

On the south shore of Lake Erie between Buffalo and Toledo are nine cities that have evolved under the same general set of conditions. All occupy low, monotonously level, lake-plain sites; all have improved harbors with depths of 18–20 feet; all enjoy situation advantages with respect to the Appalachian coal-fields and the iron-ore-producing fields of the Upper Lakes region; all present landscapes that have developed through the same sequential stages of human occupance from that of rural simplicity to that of commercial and industrial complexity. Five of these cities now have progressed to a period when industrial landscapes are dominant.

Lorain, Ohio, located on the level lake-plain surface at the debouchure of the navigable Black River 70 miles east of Toledo and 200 miles west of Buffalo is one of these cities,

Fig. 1. Representative of the cities with a coal export and iron import trade, and also of those cities whose industrial imprint now dominates their character, this city, although smaller in size than some, epitomizes the present status of all these cities; and may, therefore, be taken as a type city.

The Lorain site has had at least 125 years of human tenure during which time the landscape has responded to occupation by Indian tribes; has experienced the stimulus of port activities during a formative period of early white settlement; was

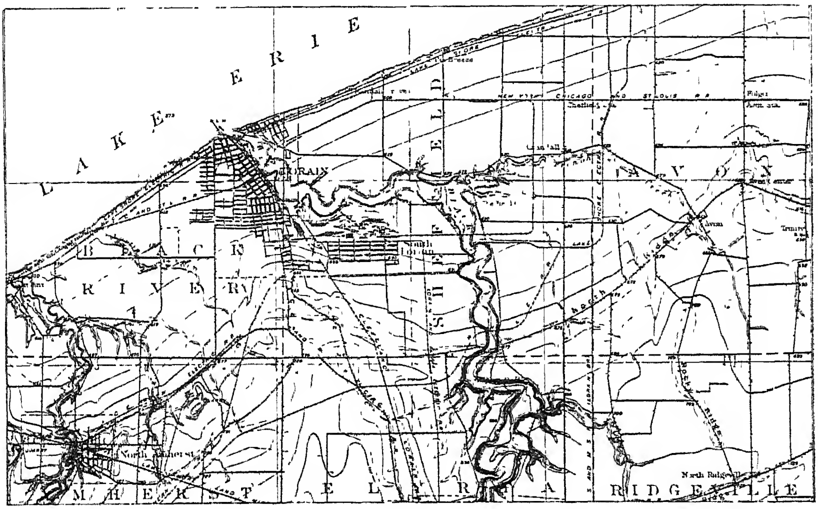

Fig. 1. Location of Lorain, Ohio, at the mouth of Black River (Oberlin Quad., U. S. G. S , scale 1: 62,500).

stimulated to growth during the early period of agricultural development; has been subjected to commercial adversity when the railroads first came; and has experienced a complete revival of trade and phenomenal modern industrial development in later years. Such changes have produced manifold urban forms, changed the urban functions and have been the means of producing a changed urban pattern.

In the following pages of Part I, the natural environment is described; Part II, the forms, functions and pattern of the past landscapes are depicted; and in the succeeding chapters of Part III the modern landscape of Lorain is described and analyzed.

Part I. Natural Environment

A. Regional Aspects

1. *Lake Erie and the Great Lakes Chain*

From the mouth of Black River there extends toward the northeast, north, west and southwestward the broad expanse of Lake Erie. Although one of the smallest of the Great Lakes, being 241 miles in length and having a maximum width of 57 miles, Lake Erie is one of the most important links in this great chain, the largest inland waterway system in the world. By land route the distance from Buffalo, at the east end of the lake, to Toledo, at the other end, is 304 miles, or a reasonably good day's drive by automobile.

Lake Erie is the shallowest of the five Great Lakes having a maximum recorded depth of 210 feet but averages very much less than that. In fact, approximately one-half the area of the lake is less than 60 feet in depth. The smaller size, its shallowness and its more southerly location render Lake Erie less turbulent in stormy weather and less dangerous to navigation than the other Great Lakes. Among navigators Lake Erie does not command the respect accorded the other lakes and especially that of Lake Superior.

Four states (Ohio, Michigan, New York and Pennsylvania) and Canada have frontage on this waterbody which offers certain transportational advantages not enjoyed by many states. To any city located on its shoreline immediate contact is possible with any other city similarly located and is an advantage which, though placing a certain stamp of character upon the city, is a stimulus to growth and importance. And through an improved system of connecting channels, including the Detroit River, Lake St. Clair, the St. Clair River, the Straits of Mackinaw and the St. Mary's River, these regional contacts are extended infinitely more to include the entire chain of Great Lakes, with an aggregate shoreline of 8,300 miles, and upwards of one hundred cities and towns along it. Moreover, each town and city has its own trade area which it serves. In this way the sphere of trade and influence often reaches far beyond the shoreline of these Great Lakes. Like a magnet they draw the raw materials which originate in the service areas of these coastal towns and cities. The force that attracts raw materials to the lake shores is the low freight

rates which prevail on this 1,000 mile waterway system. Thus the sphere of influence and trade potential becomes vastly extended by reason of Lorain's location along the shoreline of such a waterway system.

2. *The Lake Plain*

On the landward side and running roughly parallel to the southern shoreline of Lake Erie is the Lake Plain. From a point near Cleveland, Ohio, where the plain is about three miles in width, it spreads out fan-like increasing in width toward the southwest until it attains a maximum width of 50 miles or more south of Toledo. Immediately south-eastward from the mouth of Black River and about at right angles to the shoreline, the lake plain is thirteen miles in width.

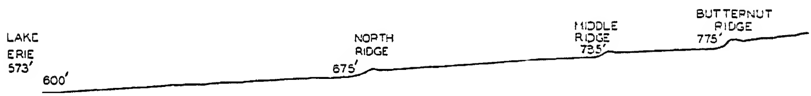

FIG. 2. Profile of site of Lorain, Ohio, showing Lake Plain Terrain.
Total width, 12 miles

Though the lake plain appears to the eye to be a perfectly level plain, actually it rises towards the south approximately 180 feet in twelve miles, or 15 feet per mile. Instead of being a continuous and uniform slope the rise is in three step-like surfaces each higher than the one on the north of it; the southernmost one being almost two hundred feet above the plane at the present lake shore. Each surface merges with and is bordered by a sandy, gravelly ridge averaging 20 to 30 feet in height and having a remarkably even crest. Each ridge in position forms a kind of retainer wall for the higher surface and as a distinct abandoned shoreline feature to the lower surface. (Fig. 2.) These ridges mark the shorelines of glacial lakes that stood over the land during the last stages of the glacial period. This marginal glacial lake at its maximum stage stood at an elevation of 790 feet and was known as the Maumee Lake. The ridge that marks the shoreline of glacial Lake Maumee is known locally as Butternut Ridge. As the continental icecap receded a lower outlet across the state of Michigan, called the Uhly-Cass River, lowered the level of the lake to an elevation approximately 735 feet. The waters stood at this level sufficiently long for another ridge to be formed

along the shoreline. This, the second stage of the lake was known as Whittlesley Lake and the beach ridge formed by it is known as Middle Ridge. As the ice melted back still further a lower outlet was opened which again dropped the level of the lake from that of the Whittlesley stage to an elevation approximately 675 feet. This stage of the lake is known as Warren Lake and the beachline formed by its waters is North Ridge.[1] The present level of Lake Erie is about 20 feet below the level of the surface at the shoreline and about 100 feet lower than the general level of North Ridge.

Since these three well developed surfaces represent the former lake bottoms of pre-existing glacial lakes they have a minimum slope of 10 feet per mile which increases to 30 feet per mile as each ridge or abandoned shoreline is approached. Beginning at the mouth of Black River and going in a southeasterly direction, the lake plain surfaces have widths of six, four and three miles respectively, or a total width of thirteen miles for the lake plain at this point.

Although seldom having a width of one-fourth of a mile, and often very much less, the beach ridges stand out as conspicuous features because of their elevated character, their uniform height above the lake plain, and their good drainage. This is in contrast to the low, level and poorly drained surfaces of the lake plain. There are a few short and discontinuous ridges intervening between those already named, but the importance of these is local and not general as is true of North, Middle and Butternut ridges.

(a) *Geological section*—The upper portion of the mantle rock over the lake plain consists of a stratum of thinly bedded and fine lake clays, four to ten feet in thickness. These clays are the sediments deposited on the bottoms of the glacial lakes that once stood over the lake plain surface. They are characteristically sticky during wet weather and relentive of surface waters.

The lower portion of the mantle rock consists of unassorted and unstratified glacial drift which varies in thickness from 0-80 feet or more, depending upon the nature of the preglacial surface over which it was deposited.

The bedrock of the region is that of the Ohio Shale. This formation is a thinly bedded, black, carbonaceous, slaty shale

[1]Geology and Mineral Resources of the Cleveland District, Bulletin 818. U. S. G. S. by H. P. Cushing, Frank Leverett and F. Van Horn, p. 96.

underlying the glacial drift. When eroded by streams this shale has the property of standing in an almost vertical cliff. Post glacial streams have in places eroded through the mantle of glacial drift and have cut their valleys from the shale bedrock. In such places the valleys are deep and gorge like.

(b) *Glaciated Plain*—To the southeast of the Lake Plain and immediately south of Butternut Ridge, extends the glaciated plain of Central and Northern Ohio. Its surface is level to gently rolling in the northern portion, where the glacial drift is thick and the preglacial topography less accentuated; but gives way toward the south to that of a distinctly hilly landscape, where the glacial drift becomes thinner and the preglacial topography more prominent. Here the topographic features are sufficiently prominent to give variety to the landscape, the glacial covering giving the landscape a subdued character. This is in pronounced contrast to the abrupt slopes and rock outcrops so characteristic of the unglaciated portion of the plateau. The relief increases gradually from north to south, as is also true of the general elevation above sea level. The glaciated portion of the Allegheny plateau merges into the till plain without a significant change in the character of the terrain.

3. *Appalachian Plateau*

The central Appalachian Plateau extends over southeastern Ohio, western Pennsylvania, almost all of West Virginia, a portion of eastern Kentucky and western Virginia, as well as the westward extension of Maryland. From the mouth of Black River to the southeastward, it is 160 miles to Pittsburgh; 200 miles to Connellsville; and approximately 300 miles to Charleston, West Virginia.

This plateau is a maturely dissected upland with an intricate dendritic pattern of drainage. The streams have cut their valleys so deeply into the upland surface as to develop a bold and rugged topography, which is often referred to as the "Allegheny Mountains." The relief is greatest in the eastern and southern portions of the central plateau where valleys 1000–2000 feet deep are found, and less pronounced in the northern and western parts where the relief is no greater than 300–400 feet.

Interbedded in the rock strata of this rough country are several seams of workable bituminous coal that constitute in

the aggregate the most extensive bituminous coal deposits known. Moreover, the territory contains at least twelve important producing fields in which are found many grades and varieties of coal. From the very high-volatile low-carbon steam coals to the low-volatile high-carbon coking coals the entire gamut of bituminous coal grades is run. The great number of coal grades makes possible the wide range of uses to which the coal may be put.

Although the main stream valleys of the plateau are narrow and circuitous, they favor the exploitation of these coal resources from the north and west. Such streams as the Big Sandy, Kanawa, Little Kanawa, Guyandot, Kiskiminetas, Monongohela, Kentucky, Licking rivers and Twelvepole Creek, as well as some of the important tributaries of these streams, flow in a northwesterly direction into the Ohio River. The principal streams of Ohio flow in a south or southeasterly direction as tributaries of the Ohio River, such streams as the Mahoning, Muskingum, Tuscarawas, Kokosing, Hocking, Licking rivers and many smaller streams, thus forming natural routes connecting the Allegheny Plateau with Lake Plain. Along these river valleys, and often many of the smaller tributaries of these streams have been constructed the railroads that serve the several different coal fields.[2]

4. *Climate and Aboriginal Forest Cover*

The mouth of Black River is near the borderline between Koeppen's Dfa and Dfb types of climate, that is, a constantly moist climate with at least one summer month having a mean temperature of 72° F, Fig. 3. The winters, however, are sufficiently cold that a shelf of ice 1–10 miles in width and 8–10 inches in thickness forms around the margins of Lake Erie and navigation is closed for three to four months.

Ordinarily the length of the growing season is expected to increase from north to south in the northern hemisphere, but southward from the shoreline of Lake Erie the length of the growing season decreases. Two sections, one along the Lake Erie shoreline and the other in the extreme southwestern corner of Ohio have growing seasons longer than 192 days. Elsewhere it is shorter, decreasing to 150 days in the higher

[2]The valleys of the Mahoning, Muskingum, Tuscarawas, Kokosing, Hocking, and Licking rivers and those of Little Storms Creek, Leading Creek, Short Creek, Wheeling Creek, Yellow Creek, Cross Creek, Wegee Creek, Raccoon and Chickamanga Creeks, are some of those utilized by railroads.

eastern portion of the state. The average date for the first killing frost in autumn along the lake shore is October 30th and that of the last killing frost in spring is April 15th. This is ten days later in the autumn than in the southern part of the state and over a month earlier in spring than in some other parts of the state. The autumn season is a long, mild and delightful one; but the cold, raw northerly winds from off the lake in spring are disagreeable even though the temperature remains above freezing.

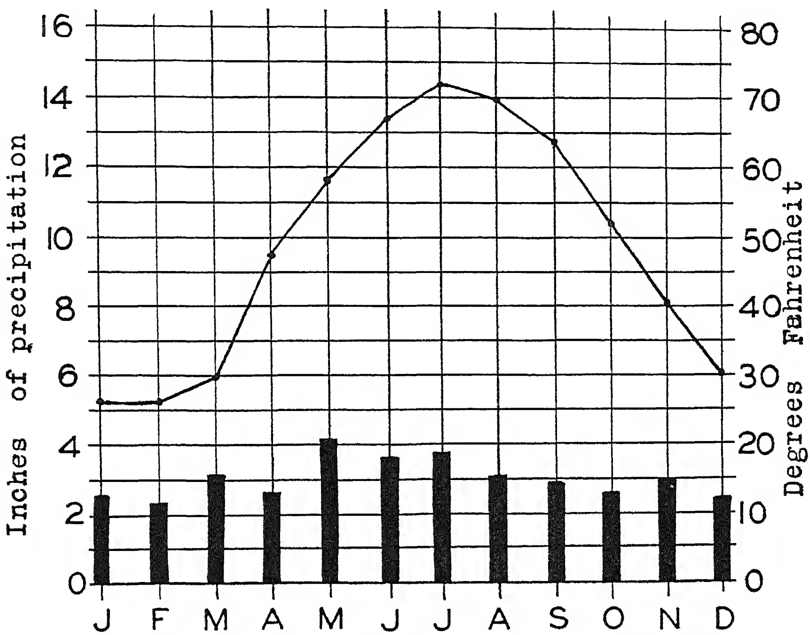

FIG. 3. Climatic Chart. Upper line shows mean monthly temperatures; lower vertical bars represent mean monthly precipitation.

At the time of the Indian occupance of the Lorain site, there was over the entire surface of the Lake Plain a magnificent forest of mixed hardwoods. Smith, a young captive of the Delaware Indians, wrote, "The timber is black-oak, walnut, hickory, cherry, black-ash, water-ash, buckeye, black-locust, sugar-tree and elm; there is also some land, though comparatively, but small, where the timber is chiefly white-oak or beach—this may be called third rate. In the bottoms, and also many places in the upland, there is a large quantity of wild apple, plum, and red and black haw trees. It appeared well watered,

and plenty of meadow ground, intermixed with upland, but no large prairies or glades, that I saw or hear of." . . . "About the falls (ridges) is thin chestnut lands . . ."[3] Because it was in the Temperate Zone of cyclonic storms, and because this was in a transition zone (between Koppen's Dfa and Dfb types of climate) with a July temperature of 72° F and a January temperature of 26° F, the region had also a forest transition between the Southern Hardwood (Oak-Hickory) Forest, the Northeastern Hardwood (Birch-Maple-Hemlock) Forest, and the Southern Chestnut (Chestnut-Chestnut Oak-Yellow Poplar) Forest. The climate was just cold enough for the southern extension of the northeastern forest and warm enough for the central hardwood forest and the soils were thin enough on the beach ridges for the Chestnut associations.[4] Moreover, the mean annual rainfall of 36 inches was well distributed, 57% falling in summer and 43% during the winter months.[5] With the Dunkirk clay soils that retained moisture and with the growing season lengthened to 167 days or more by the ameliorating influence of Lake Erie, forest trees grow to unusually large size.

The dense forests accentuated the poor drainage of the youthful Lake-Plain so that much of the surface was marshy. In crossing this section of the Lake Plain, Smith says, "Here the land is generally good, but I found some difficulty getting round swamps and ponds."[6] And again, "The only refuse (of land) is some swamps, that appear to be too wet for use, yet I apprehend a number of them, if drained, would make excellent meadows." The best drained surfaces are those close to the streams and immediately adjacent to the lake shore, where short ravines have had time to develop since glacial times.

B. SITE CHARACTERISTICS

1. *Black River and its Estuary*

Black River is formed by the confluence of East and West Branches of Black River approximately ten miles from its

[3]Smith, Col. James. An account of the Remarkable Occurrences in the Life and Travels of Col. James Smith during captivity with the Indians. John Bradford, Lexington, 1799, p. 17.

[4]Shantz, H. S. and Zon, R. Atlas of American Agriculture, Natural Vegetation. Government Printing Office, 1924, pp. 13–14.

[5]Curtis, H. S. Industrial Survey of Lorain, Ohio, 1928, p. 4.

[6]Smith, op. cit., p. 25.

mouth. The system is post glacial and rises near the crest of the low drainage divide in Central Ohio and flows northward to Lake Erie.

In crossing northern Ohio these streams flow through glacial drift except in the lower six miles of their course where the valley of Black River has been partially carved out of the Ohio Shale. The fall of the river from the confluence, ten miles upstream and almost a quarter of a mile below the falls, to mean lake level is 52.6 feet, but practically all of this fall is concentrated in the upper half of the river. Ten miles upstream the branches of Black River flow over an exhumed sandstone divided to form the waterfalls in Cascade Park at Elyria.

Since the close of the glacial period Black River has cut its gorge-like valley through the layers of lake clays, then through the glacial drift, and in places several feet into the Ohio Shale formation. The depth of the gorge increases upstream. Near the mouth and where the bluffs coalesce with the Lake Erie shoreline, the river flows about twenty feet below the surface and six miles upstream it is seventy feet below. Because the lake plain surface rises toward the south at about 10 feet per mile and because mean lake level extends almost six miles upstream, the gorge increases in depth toward the south. Near the mouth of Black River the gorge is 20 feet in depth; three and one-half miles upstream the depth increases to 50 feet; and ten miles upstream the depth is 90 feet. (Fig. 1.)

The gorge of Black River is slightly less than a quarter of a mile in width except in places where the river in meandering has undercut a bluff and widened the valley. But in no place does the width exceed one-half a mile and in most instances it is about one quarter of a mile.

The tributaries of Black River are few in number and small in size. French Creek a small tributary eight or ten miles in length is the largest one. The initial slope of the Lake Plain is much as it was following the lowering of the glacial lake waters and little disturbed by subsequent stream erosion. The upland surface slopes toward the lake and Black River gorge is an abrupt feature which interrupts the general continuity of the Lake Plain.

Except during spring flood season there is no appreciable current in the lower portion of Black River, even then it never

interferes with navigation but may cause ice jams at or near the mouth of the river. In most of its lower course the stream meanders back and forth across its low, marshy and cattail-covered flood plain in broad sweeping curves a quarter of a mile or more across. Occasionally the main channel of the stream undercuts a bluff to form a steep cliff which overlooks the flat, marshy flood-plain.

2. *Shorline of Lake Erie*

Except for the small delta filled embayment at the mouth of Black River the Lake Erie coastline is an erosional one twenty-five miles eastward to Cleveland. It is therefore cliffed, bold and uninviting to mariners. From Black River westward, the shoreline has been eroded for the most part from glacial drift and is straight and much lower than eastward where it is eroded from the Chagrin shale and stands in cliffs 60–80 feet above the lake.

Before modernization of the lower course of Black River and the dredging of a channel, the river mouth was choked by deposition of its own sediment. The greatest handicap was the sandbar obstruction at the mouth of the stream where the water was about three feet in depth. The sandbar developed into a real barrier only after the strong lake currents driven by northerly winds accentuated the deposit until it literally chocked the mouth and ponded the river. Not infrequently it was necessary for workmen to " . . . plow out a channel which the current would enlarge sufficiently to allow the passage of the bottled-up vessels."[7] Even in its natural state, the Black River harbor[8] was one of the best on the Great Lakes. From the mouth of the stream to the head of navigation the natural depth was ten to fifteen feet and the natural channel about one hundred feet in width.[9]

At present most of the sediment is deposited where the stream enters pool at the head of navigation.

The gradient of Black River is so slight that the stream meanders aimlessly back and forth across its floodplain. Mean lake level extends for six miles upstream and this portion of the stream is in pool, which, so far as navigation is concerned, may be considered an arm of the lake.

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[7]G. Frederick Wright. History of Lorain County, p. 89.

[8]Black River Harbor was the term given to the entire navigable portion of the river from the mouth to the head of navigation three miles upstream.

[9]House Document No. 985, 64th Congress, First session, p. 4.

Part II. Sequent Stages of Human Occupance

A. LANDSCAPE DURING THE INDIAN PERIOD

1. *Indian Occupance*

The region which included the mouth of Black River[1] in northern Ohio was occupied by Indian tribes for an indefinitely long time before the coming of the white man. As late as fifty years before the appearance of the first white settler (1807), the region was known to have been occupied by the Delaware Indians, later by the Ottawas, and immediately before the time of the white surveyors, by the Wyandots.[2] In 1755 the immediate site at the mouth of Black River is known to have been the place of a Wyandot Indian village,[3] and a rendezvous for Indians engaged in hunting, fishing, and making intermittent raids upon the bordering white settlements in Western Pennsylvania and New York.[4] In this same year, a youth named James Smith, who had been taken captive by the Delaware Indians from a military camp in western Pennsylvania, visited the lake shore in the course of his hunting with the Indians. In coming to the lake shore and traveling east along it Smith says, "Where some time in the afternoon we came to a large camp of Wiandots at the mouth of Canesadoohorie (Black River)."[5] This establishes fairly definitely the camp on the west side of the stream. This campsite was the first form of human occupance on the site of present-day Lorain.

Thus, the first people to occupy the site at the mouth of Black River were exploiters of the wild animal life indigenous to the region. The great forest cover he left unmolested except to supply his few immediate needs. The Indian, therefore, built no permanent establishments or lasting institutions whose remains could be examined by posterity. Except for the few occasional arrowheads found, charcoal, fish or clam-shell remains left, an occasional Indian mound or breast works preserved, and the place names adopted by the white settlers,

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[1]The name Black River is here used instead of the Indian name, Canesadooharie, even though the stream was not so named until after the white man came.

[2]Wright, George F. History of Lorain County, p. 32. Lewis Publishing Company, 1916.

[3]Ibid., p. 77.

[4]Smith, op. cit., p. 17.

[5]The historical account, which is written in considerable detail from a journal the author kept, gives no account of crossing the river.

there is little to testify to the long period of Indian occupance. He was a hunter and warrior who engaged in tribal struggles, before the coming of the white settler brought a newer and more powerful enemy. The peculiar nature of the resource he exploited, non-existent today, caused the Indian to be semi-nomadic in his mode of life.

Nevertheless, the Indian occupance of the land, semi-permanent though it was, sufficed to retard the white settlement of this site in northern Ohio until an agreement could be made with the Indians and they could be induced to move farther westward. Connecticut's claim to the lands of the Western Reserve was based upon a land grant to the Connecticut Colony by King Edward II, of England, in 1662.[6] However, the Indians occupied the territory and they were reluctant to give up excellent hunting territory which they deemed their inalienable right to occupy.

2. *Indian Removal*

The Treaty of Ft. Industry, July 4, 1805, was consummated between the United States Government and the chiefs and warriors of the Wyandot, Ottawa, Chippewa, Munsee, Delaware, Shawanese, and Pottawattamie tribes.[7] This agreement gave to the white man the title to the land of the Connecticut Western Reserve west of the Cuyahoga River. This was nine years after the titles to the lands east of the Cuyahoga River had been given to the Connecticut Land Company, corporate agent of the State of Connecticut. Those lands between the western line of Pennsylvania and the Cuyahoga River, or the eastern part of the Reserve, had been surveyed in the years 1796–97.

In Surveyor Tappan's manuscript field notes, written in 1807, after the survey had been made and while he was engaged in equalizing the lands, he says, "At the period of which I am writing not a person, white, red or black, lived on the tract of country we were about to explore."[8] This meant

[6]This claim embraced all the lands between the forty-first and forty-second parallels of north latitude, and from Providence plantations on the east to the Pacific Ocean on the west. Conflicting claims afterwards arose with other states. Final settlement between the United States and Connecticut gave that state the "exclusive right of soil to the 3,800,000 acres" included in the Western Reserve. Wright, op. cit., p. 40.

[7]Wright, op. cit., p. 62.

[8]Manuscript notes of A. Tappan, 1807, Western Reserve Historical Society Library, Cleveland, Ohio.

that in the brief period of two years all of the Indians living in that vast tract of aboriginal territory, comprising more than three and a quarter millions of acres (3,366,000 acres), had evacuated in accordance with their treaty agreement.

B. THE LANDSCAPE DURING THE PIONEER PERIOD

1. *Interim Period*

Following the Indian removal there was a brief interim period when the Western Reserve territory was occupied only by surveyors of the Connecticut Land Company, and possibly some wandering Indians. There was, therefore, no gradual transformation of the landscape from the period of Indian occupance to that of white settlement. Instead the period between 1805 and 1810 is marked by little change. During this interim period, there was considerable preparation to occupy the lands west of the Cuyahoga River. The surveys were made and the lands equalized. So that equal shareholders in the Connecticut Land Company participated equally in the drawing of the western lands. The value of the inferior townships was made equal to that of the best townships by adding on tracts of land reserved for equalization purposes. This method resulted in some holdings being very large, while others were normal sized townships.[9] Time was also consumed in establishing the ownership of the land which was drawn by lot after the surveys had been made and the lands equalized. Stockholders who became the owners of a township of land then subdivided the land and sold parcels to individual settlers.

Both the Indian occupance of the territory and the ownership by the Connecticut Land Company retarded the settlement of northern Ohio until a much later time than the settlement of similar lands in southern Ohio. Settlement was not long delayed after the drawing of townships and subdivisions had established the ownership of the tracts. The next year (1807) witnessed the arrival of the first permanent settlers when Nathan Perry, with Araziah Beebe and his wife

[9]The system of survey used by the Connecticut Land Company was somewhat different from that used by the Government at about the same time. Townships in the Western Reserve were made five miles square instead of six miles square where governmental surveys were made. A complete history and detailed account of the surveys in the Western Reserve may be found in the Western Reserve Historical Society volumes.

came west to the mouth of Black River.[10] They "saw that the country was fair to look upon and so built a log cabin on the site of the deserted (Indian) village." From this year onward settlement from New England was more or less continuous. It was slow in starting and was interrupted most by the beginning of hostilities between the United States and Great Britain in 1812.

2. *Village Birth*

The germ cell of the village organism at the mouth of Black River was really planted when in 1812 James Reid built a large house to be used as a dwelling and tavern. The Reid House stood not far from the edge of the bluffs and overlooked Black River.[11] A few years later, the "Mouth of Black River" Post Office and the office of the first Justice of the Peace were housed in the same building. Few settlers lived in the new Western Reserve country and the Reid House was constructed more in anticipation of its service to incoming settlers than to the actual service to local inhabitants it rendered at the time it was built.

Several advantages of the site at the mouth of Black River gave some assurance that the place had possibilities of considerable growth. Black River was the first navigable stream west of Cleveland, at the mouth of the Cuyahoga River. Moreover, the slight embayment along an otherwise cliffed coastline offered some degree of safety for the small sailing craft of that day, and the natural Black River harbor was one of the best on the Great Lakes. For those new settlers who came by boat from Buffalo and who wished to get as near as possible to their lands, located in the recently surveyed western portion of the Western Reserve, the mouth of Black River was the logical stopping place. Before roads had been cut through the dense forest wilderness, it was considered easier and safer to continue the journey by boat west from Cleveland than it was to stop at Cleveland and continue the overland journey to their lands.[12] A few years later, when the Fire

[10]Wright, op. cit., p. 94.

[11]The original Reid House stood near what is now the intersection of Broadway and Erie Avenue. Moore, W. M., "For a Greater Lorain." Bulletin of The Cleveland Trust Company, p. 3.

[12]Ichabod Terrell, the first settler in Ridgeville Township, came to Cleveland and thence overland to Ridgeville. To go to Ridgeville required "two days and three nights in route from Rocky River." They had to "cut a wagon road from Rocky River to the place of destination." Rocky River here referred to is just west of Cleveland. Wright, op. cit., p. 92.

Lands were opened for settlement the importance of Black River's position just east of these lands was emphasized.[13]

Although the War of 1812 retarded somewhat the settlement in the Western Reserve, it was not long after 1812 that settlers began to enter in considerable numbers. Immigrants with their belongings came and stopped temporarily at the mouth of the river before moving to their homesteads. Thus the first break-of-bulk functions of the embryo village were associated with the handling of passengers and their belongings, rather than with cargo freight.

Another industry which was later to play an important part in stimulating the village nucleus was that of shipbuilding. With an increasing number of settlers coming west and an increase in cargo tonnage of supplies for the settlers, there was a demand created for ships. As early as 1819 the General Huntington, the first ship to be built at the mouth of Black River, was launched. It had been constructed by F. Church out of the hardwood materials found near the river. The year previous, two men, who had owned shipyards during the war, took grants at the mouth of Black River for the purpose of constructing ships.[14] Early shipyards were small and occupied the narrow flood plain close to the mouth of the river and along the lake shore immediately east of the river. These early ships were small sailing vessels constructed of hewn timbers and planks, but offered employment to a few carpenters who added to the village nucleus.

As evidenced by the activities described above, there was near the mouth of Black River the beginnings of an urban growth, but, at the time, the organism was so clearly attached to its rural surroundings as to be inseparable. This urban nucleus had in no way shown itself to be an independent entity. Hence a consideration of the region immediately adjacent to and surrounding this urban nucleus seems essential to an understanding of the further growth of the village.

3. *Pioneer Developments*

The pioneer was a sedentary agriculturalist who came West to occupy the land acquired from the Connecticut Land

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[13]The Fire Lands was a tract of land, consisting of 781 square miles or about one-half million acres, located in the western portion of the Western Reserve. This name was given to the tract because the State of Connecticut donated portions of it to citizens who had suffered destruction of their property during the Revolutionary War.

[14]Wright, op. cit., p. 87.

Company. Whenever possible he came in the early summer to escape the privations of the cold Ohio winters, to make a clearing in the forest for a subsistence crop the first season

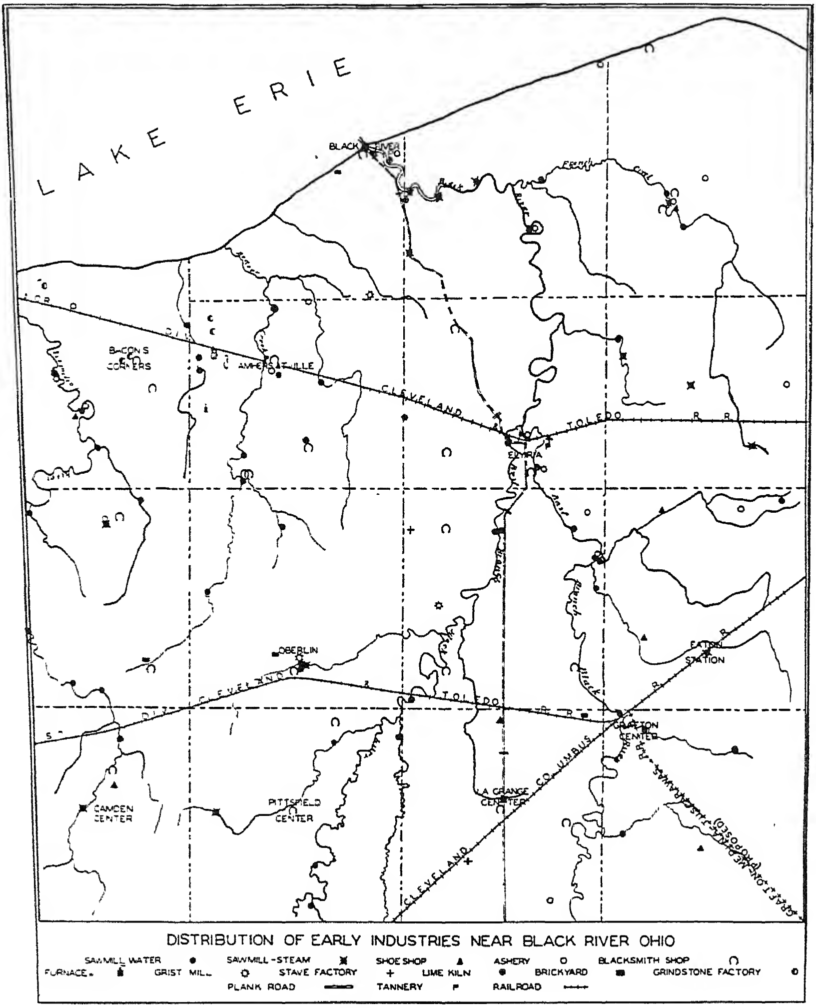

FIG. 4. The pioneer industries of the neighboring region in 1856 which furnished the impetus to early urban growth and importance of Charleston.

and to be thus prepared for the hardships of the approaching winter.

From the forests which the pioneer immediately set about clearing, he obtained his fuel, materials for his home, his furni-

ture, his fences, and many of his implements and tools. Even the fruits, berries, nuts, and wild honey were gathered from the forests and were important articles in his diet. The first money with which he purchased salt, clothing and paid his taxes was obtained from the sale of pearl and pot-ash made by burning the hardwood timber. Unlike the Indian who depended upon the generosity of nature for his food, the Connecticut Yankee was an exploiter of the soil and the forest cover.

Manufacturing industries in the pioneer and dominantly rural community were slow to make their appearance. Beyond the ability to make and repair shoes, the skill to fashion from wood the crude farm implements or tools and some blacksmithing there was little necessity for skilled mechanics or artisans.

The necessary manufacturies of the new country were the grist and saw mills. Suitable sites along the stream courses that cross the Lake Plain were the first to be occupied by the pioneer. Water wheels were established at waterfalls and along races cut across meanders in the streams. The principal objection to the early water wheel was that on many streams the fall was insufficient to develop much power, the streams had small volume, the water wheels became frozen in winter, or they failed entirely during the drought. The most dependable water wheels were those on Black River, located in Sheffield Township, now the present corporate limits of Lorain, and the other at the waterfalls in Elyria.

In spite of these early manufacturing attempts they were coincident with the subsistent agricultural development and were supplementary to it.

There was little surplus and no sale for farm produce. About the only farm income was from the sale of "Black Salts," made from ashes of burned, hardwood trees. This crude potassium salt was valuable enough when properly concentrated, to withstand the high transportation cost to the eastern markets. Each farmer's black salts were further concentrated into "Pearlash" or "Potash" at an "ashery." (Fig. 4.) This product was then taken to a trader at the mouth of Black River where it was exchanged in the proportions of one-third for cash and two-thirds for supplies. This money enabled the farmers to pay their taxes and buy salt, tea, and cotton goods which required cash.[15]

[15]Boynton, op. cit., p. 11.

C. LANDSCAPE DURING PERIOD OF GROWTH

1. *Agri-functional Character of the Village*

Scarcely twenty years after its inception the settlement at the mouth of Black River had crystallized into an incorporated village, taking the name of Charleston.[16] The growth from a rural settlement to a village with definite outlines was a slow but steady one. In 1834, the village townsite was surveyed and platted into lots by the Lorain County Surveyor. A public square, city blocks bounded by streets and lot lines tended to divorce the village from its purely rural surroundings and to give it the first manifestations of an independent existence.

Early growth of the village into a chartered town is attributed by most historians to the shipbuilding industry. But when the problem is studied closely this early stimulation seems to be more closely related to the break-of-bulk character of the village. Shipbuilding was a much more concentrated industry and contributed more sensationally to the growth of the urban nucleus than did the break-of-bulk activities, but, the business activities attached to the incoming ships, with new immigrants and supplies, and the trade that originated in the surrounding hinterland were real stimuli in the growth of the village. A commission warehouse for the storage of farm products and capitalized at $50,000 was the largest business establishment of the town.[17] The large stave landing on Black River, the two lumber yards that exported lumber products, the Reid Hotel, a blacksmith shop, and even many of the schooners that frequented Black River harbor and operated in the carrying trade, all gave break-of-bulk character to the new town.[18]

The village physiognomy retained many of the resemblances arising from its regional dependence and rural parentage. The sprawling aspect of the town plan, the scattered houses with acreage plots surrounding them, the rural interests of the business houses and the rural lineage of its leading men, gave

[16]Wright, op. cit., p. 290.

[17]Sixth Census of the United States. Government Printing Office.

[18]In 1835 the principal business men were: William Jones, merchant; Gates and Green, general merchandising; Delos Phelon and O. Scot, forwarding and commission merchants; Daniel T. Baldwin, farmer; Barna Meeker, proprietor of the old Reid House; A. T. Jones, blacksmith; E. Miller, shoemaker; Thomas Brown, tailor; W. E. Fitch, stave dealer; Quartus Gillmore, farmer and justice of the peace; and Conrad Reid, postmaster. At least five or six shipbuilders, most of whom operated their own ships in the carrying trade, should have been added to this list. (Wright, op. cit., p. 289.)

the village a distinctly rural aspect. Men employed as commission traders, stave dealers, the twelve men engaged in furniture making, and much of the exchange trade of the four stores further emphasized the regional dependence of Charleston.[19]

But the town character was not entirely dominated by the agricultural surroundings. Shipbuilding had grown to be a major industry locally and was fast gaining a reputation that reached well over Lake Erie. Shipbuilders, ship's carpenters, caulkers, and sailors appeared as an important stratum in the social order. Fishing, although considered a minor industry in relation to shipbuilding, engaged the attention of a few individuals and fishing shacks were found on the banks of Black River and along the lake shore.

2. *The Durand Survey*

The village plan as surveyed by Edward Durand in 1834 consisted of seven city blocks. The townsite pattern gave the appearance of a blunt wedge driven northward between the Black River and the lake shore, stopping just short of these bodies of water. This left a marginal strip of land on the lake shore and Black River that was subdivided into lots with frontage along these bodies of water. One side of the wedge was Elyria Avenue which followed roughly parallel to the bluffs of the river and the old road to Elyria. Thus, the direction of the street was almost exactly southeast. On the west side of the plat the street, later called Oberlin Avenue, followed the center of the lot line which trended south.[20] The converging ends of the townsite wedge were joined by First Street which paralleled the lake shore and was surveyed less than two hundred feet from the shoreline. In this way the first townsite of Charleston was planned so as to utilize as efficiently as possible the point of land at the mouth of Black River. Shortly after the survey, town lots were sold and the village granted a charter by the Ohio legislature in 1836.

[19] Sixth Census, 1840, op. cit.

[20] The articles of incorporation relative to the boundary lines of the town of Charleston provided that: "Commencing on the shores of Lake Erie, center of Lot 26, Tract 2, south through center of Lot 26, Tract 2, till an east line will strike the southwest corner, set off from Lot 6, Tract 1, thence east across lots 6, 5, 4, 3 to Black River, thence down east bank of Black River, along east pier erected by United States to northern extremity thereof, thence through Lake Erie to place of beginning." The officers of the new town were to be: a mayor, a recorder, five trustees, an assessor, a treasurer, a street commissioner, a marshall, and "such other officers as the town shall create and appoint."—Acts of a General Nature, Thirty-fifth Ohio General Assembly, Vol. XXXV, 1837, p. 162.

3. *New Village Extensions*

In addition to the substantial support of the village, already referred to, there was a series of proposed developments that served to buoy up the new and ambitious village. This speculative buoyancy was manifest in the form of village extensions (subdivisions) and of high land values. In 1835, a five-acre tract adjoining the Durand Plat of Charleston was purchased for $1000 an acre and subdivided into city lots. All the lots having been sold, another tract of six acres adjoining the previous one was subdivided. Then the entire farm from which these tracts were taken was purchased for townsite purposes.[21]

These extensions to the town plan were made largely on anticipated developments and their hypothetical benefits. In 1832, the Ohio Railroad was surveyed through Black River. The following year work was started on the Ohio Canal which was expected to terminate at the mouth of Black River. When the canal was finally projected down the Cuyahoga River instead of the Black River, their hope for a canal was not entirely abandoned. The Ohio Legislature in 1837 ordered a survey made of the proposed Killbuck Creek-Black River Canal, which was planned to join the Ohio Canal system at Coshocton via Wooster.[22] These projected and planned proposals imposed on the new town of Charleston an inflated expectancy. When none of the projects was completed, the town suffered a relapse. Although the town plan as extended during the speculative times remained a fixture, the town functions regained normalcy as one by one the projects failed.

4. *Population Increase*

Black River Township,[23] in 1840 had 668 inhabitants. A large proportion of these people lived on farms, were definitely associated with agricultural development and were, therefore, not considered a part of the town. Listed under occupations in commerce, internal transportation, fishing, and manu-

[21]The sale of this farm (Conrad Reid farm) was contracted for the sum of seventy-five thousand dollars.

[22]Report of the Board of Public Works, Ohio Exec. Doc. (1836–7), No. 43.

[23]Black River Township is a civil division established in 1830 by a special act of the Ohio Legislature, because of a previous act prohibiting the formation of townships with less than an area of twenty-two square miles. The township is but one-half the average area of other townships in Lorain County, or approximately thirteen square miles.

facturing, and building are sixty who would account for a town of perhaps three hundred inhabitants.[24] One historian states that the population of Charleston "reached several hundred."[25] The growth of population during the decade 1830–40 was over 300% in the township.[26] Lorain county had a similar growth, but the state as a whole increased only 62% in the same period.[27] This extraordinary increase was due to the relatively few people that made up the urban nucleus at the time, but it also reflects the healthy expansion in those basic and substantial forms of nourishment upon which the village was dependent. Retail trade, commission and forwarding, commerce, shipbuilding, fishing and small-scale manufacturing, all contributed to stimulate this vigorous growth.

D. A DECADENT VILLAGE

1. *Effects of Railroad Expansion on Charleston*

Few greater contrasts in the evolution of an urban landscape can be presented than that experienced by Charleston during the period from 1850–70. From a vigorous, thriving, substantial organism of the former period to a decadent, lifeless, urban skeleton of 1855, is a story of urban starvation. From a town with an established commercial trade, based upon a virtual monopoly of the export trade from a large collecting territory, to a cluster of abandoned houses, commercial inactivity, and a trade circumference so diminished as to be of negligible value, are developments of painful reality in the life of Charleston.

In 1857 Charleston had three large warehouses, two hotels, several stores, two blacksmith shops, shipyards, a boarding house, a lime kiln, a steam sawmill, and many residential buildings, most of which were reminiscent of a more prosperous time rather than as a true expression of the existing time. The village functions were not in proportion to the cultural forms the town possessed. To quote, "Its hotels partially closed; its merchants departed; its warehouses were partitioned among the farmers of the vicinity for barns and fences; its corporate organization was abandoned and Charleston was placed in a

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[24]Only township data are available for this period.

[25]Wright, op. cit., p. 290.

[26]Population of Black River Township was in 1830, 209; 1840, 668. Lorain County in 1830, 5,696; 1840, 18,467.

[27]Annual Report Commissioner of Statistics, Ohio Exec. Dec. (1860), Pt. 2, p. 435.

long list of defunct paper towns."[28] Many of the cultural forms of Charleston stood as mute representatives of a time when the town had sufficient nourishment to support these establishments. Although the town was legally known as Charleston in accordance with the charter granted to it, the name fell into disuse and the town was again called Black River.

2. *Decline of Population*

Although Charleston declined in population, it is not readily recognized from the census figures because the increase of population in the rural section of Black River township during the same period absorbed much of the loss suffered by the town. Between 1840–50 there was a slight decline in the township population, but an increase of 29% in that of the county. In the decade that followed both county and township gains in population were approximately 15%, while the gain for the state was 18%.[29] In 1850 there were only 659 people, nine less than in 1840, living in the entire township and it had the dubious distinction of having fewer people than any like area in the county.[30] The old citizens, many of whom had helped to clear the land and had moved to Black River to establish industry and commerce, died, and the young men of the town moved away in response to better opportunities found elsewhere.

3. *Decline in Trade*

The decline in the trade of Charleston was in keeping with the general decline experienced by most of the ports of Lake Erie when the railroads expanded westward into Ohio. Some ports were affected adversely before others, while some cities actually experienced a stimulation to their port activities by the railroad expansion. In 1851 the Cleveland, Columbus and Cincinnati Railroad was completed from Cleveland southwestward to Columbus. The railroad passed twenty miles south of Charleston. Trade which had heretofore gained an outlet through Charleston, was immediately turned toward the villages along the railroad. The decline in traffic over the

[28]Wright, op. cit., p. 290.

[29]Population increase for the state of Ohio. Ann. Report Commissioner of Statistics, Executive Document, 1860, Pt. 2, p. 435.

[30]Sixth and Seventh Censuses of the United States.

toll, plank road, which had been built to accomodate this trade, was immediate. This development had an immediate influence upon Charleston because it meant a portion of the town's dependable, agricultural hinterland had been withdrawn. Thus the southern portion of the hinterland had been cut off by a new means of land transportation which was in direct competition with lake transportation to eastern markets. Railroads were at that time operated as individual, disconnected lines, and formed no through line or system. Because Cleveland was the terminus of the railroad, the trade territory was annexed to that city and port activities were stimulated for a time.

Another railroad was formed by the Toledo and Cleveland Company, when that corpoation consolidated into one line the four short railroad lines than in existence. The railroad ran from Cleveland to Toledo passing through Elyria, just eight miles south of Charleston. So attractive became the market in the larger town of Elyria as a consequence of its railroad, that farm products were drawn almost completely away from the port at Charleston. Another factor also militated against the port town. During wet weather the only good road across the lake plain was the plank road and the toll charged on this road increased the cost of hauling to Charleston. Indeed, farm produce that originated within three miles of the port on Black River was taken to Elyria instead of Charleston. The all-weather ridge roads to Elyria, the county seat town, enabled people to make better contact with that town than was possible with Charleston on the lake. This about sealed the existence of Charleston because it removed practically all of the agricultural hinterland upon which the town had become so dependent.

This sudden change in the diversion of the country's surplus goods reflected profoundly upon the break-of-bulk functions of Charleston and upon lake transportation from the mouth of Black River. The sudden contraction of trade and transportation was only the beginning of a struggle that followed between the railroads and steamships engaged in lake coast trade. The amount Charleston shrunk was a good measure of the degree of dependence the town had become upon the surrounding agricultural region. Charleston, being without a railroad terminus which connected with a productive hinterland, was one of the first ports to be thus affected.

Harbor Decadence—The government withdrew its support of harbor improvements after a decline in trade activities was noted. Following 1838 only one appropriation of $5,000 was made during the twenty-five years ending in 1864.[31] During the time the lake shore had advanced along the piers about 400 feet. A renewal of prospects for trade was brought about by the erection of a charcoal furnace at Charleston and by a stimulation of activities that accompanied the Civil War. In the meantime the wooden piers had rotted and the harbor was badly silted leaving only a narrow channel with a depth of seven to ten feet near the west pier. The piers were repaired in 1865–66 and the channel at once began to improve. Subsequent improvements extended the piers into the lake to prevent the long-shore currents from shifting the sand around the outer ends of the piers.

TABLE I

TOTAL NUMBER OF WOODEN SHIPS CONSTRUCTED IN THE BLACK RIVER SHIPYARDS[32]

Year	No. Ships	Year	No. Ships	Year	No. Ships	Year	No. Ships	Year	No. Ships	Year	No. Ships
1819	1	1832	2	1839	1	1846	4	1854	3	1863	2
1821	1	1833	2	1840	1	1847	6	1855	7	1866	5
1825	1	1834	5	1841	5	1848	6	1856	6	1867	6
1827	1	1835	1	1842	4	1849	1	1857	3	1868	1
1828	1	1836	3	1843	2	1851	1	1858	1	1872	2
1829	1	1837	3	1844	3	1852	5	1861	1	1873	5
1831	1	1838	1	1845	3	1853	6	1862	5	1875	1

4. *Persistence of Certain Industries*

The Shipbuilding Industry—Charleston did not die as a result of the loss of its agricultural hinterland; instead, the town contracted to a size commensurate with the established industries upon which it had to depend for support. Shipbuilding was the outstanding industry and, although there was a decreasing demand for ships as a consequence of the serious competition offered by the railroads, ships continued to be turned out at the Charleston shipyards at a surprisingly uniform rate. In the decade between 1850–60 thirty-one ships, practically all of which were schooners and barks, were built in the Charleston shipyards. The banner years were 1855–56, when thirteen ships were launched.

[31]House Document No. 985, 64th Congress, First Session, p. 4.
[32]Compiled from a list of the ships given in Wright, op. cit., pp. 305–8.

Sailing vessels, being smaller, slower and less dependable than the steamships of that period, had long since been displaced in the regular, lake-coastal trade. Schooners were engaged, for the most part, in the mixed trade that originated all over the Great Lakes system. Because this class of trade was less affected by railroad competition than was the coastwise trade, there continued to be a demand for sailing vessels. The Charleston shipyards had from the very beginning specialized in the construction of the very type of ship that was now in greatest demand. Therefore, the shipbuilding industry of Charleston did not experience as quickly or as effectively the competition between railroads and water transportation on Lake Erie.

Charleston's Iron Furnace—The first iron furnace of Charleston was erected by S. O. Edison, who owned a considerable tract of timberland south of Black River. The furnace was located on the river and in close proximity to the forest lands. This furnace is interesting more because it was an example of a new and vastly different possibility that was opening up than for the support it actually contributed to the town. It exemplified new situation advantages that were at the time undergoing experimentation. In 1845 iron ore had been discovered in the Marquette Range of Michigan, and in 1855 the locks of the St. Mary's River had been completed. This event opened an all-water route from the mouth of Black River to Marquette, the port of shipment for iron ore. With iron ore from the Lake Superior region, with the limestone brought by boat from Kelley's Island, and with the charcoal made in the "pits" on the farm of S. O. Edison, the furnace was a success from the beginning. The capacity of the furnace was thirty tons of charcoal iron per day and the prevailing price was $87.50 per ton.[33] Iron production was stimulated at the time by the unprecedented demands for iron during the Civil War. The furnace continued to operate successfully until 1871 when it was burned to the ground and never rebuilt because by that time a shortage in charcoal could be definitely anticipated. The success of the first iron furnace at Charleston definitely established the mouth of Black River as a place where raw materials for iron production could be brought together economically. However, the continued depletion of the forests at

[33]Wright, op. cit., p. 311.

the time rendered hazardous any expansion of the industry based upon charcoal as a fuel.[34]

The Fishing Industry during the Decadent Period—The fishing industry was another dependence of Charleston that not only continued during the decadent period, but increased in vitality and scope. Small interests were combined, larger boats were used and the industry began to assume large scale proportions. Nearby railroads, although not directly touching Charleston, aided the industry by opening up a market vastly larger than there had been previously. Fishing methods were also modified during the period.[35] The new method of fishing with gill nets, replaced the old method of drag seining and added considerably to the annual catch. With a bountiful supply of fish in the lake and with improved methods of making the catch, the industry was definitely established as a commercial enterprise. The fishing sloop was superseded by the steam fishing craft and the natural fishing grounds of Lake Erie contributed liberally to the support of Charleston.

E. THE LANDSCAPE OF THE EARLY INDUSTRIAL PERIOD: A REVIVAL

1. *Functional Changes*

Landscape Characteristics—Lorain, Ohio, in 1880 typifies the period between 1872–1892, and is in marked contrast to the semi-dormant, fishing and shipbuilding town of the previous period. The landscape of this period is characterized by an epifunctional development—a regeneration of urban functions. Accompanying these functional changes were: a steady growth of population, a marked revision and extension of the town plan, a renewal of its commercial activities, a striking change in the character of the town's business, a decided reversal in the direction of traffic on Lake Erie, and a reincorporation of the town. Moreover, the many changes came suddenly and without much of a foundation of urban heritage which

[34]When asked one day whether the plant made money, Mr. Edison replied, "In 1865, we cleared $65,000." Ibid., p. 312.

[35]The drag seine, "the net of Biblical fishermen, was in use during the early eighteen-fifties. Then followed the pound net, 'a line of woven cord suspended on poles driven into the lake bottom, stretched in a straight line and ending in a circular pocket.' Fish, following the long straight leader, would enter the pocket and were unable to find again the opening by which they entered. The last stage in the evolution of fishing methods came with the gill net. It is a mesh net ingeniously designed to slip over the head of a fish and tighten just back of the gills."

characterizes the development of most urban organisms. From the former period was inherited the main urban skeleton, already described, but during this period, many new additions were made. The town's sudden awakening and growth were not unlike a mild town boom. Accordingly, the regional relationships of the town were vastly extended and enlarged to give the town a dependable, if not unique, means of nourishment that made for and assured permanency to the new organism.

The urban landscape of 1880 contained new cultural forms hitherto not identified with the town. A railroad entered the town from the south and acquired a large holding of land along Black River; three coal-loading docks, one ore-unloading dock, three planing mills, a stove factory, and the many ships that frequented the harbor were new cultural forms that signified a revitalization of port activities had occurred.[36] These forms also suggested that a change had occurred in the relative importance of break-of-bulk activities as compared with shipbuilding and fishing, the industries that kept alive the town during the former period.

Growth of Population—The population of Black River township increased from 838 in 1870 to 1595 in 1880, a gain of 90%. During the following decade the population gain was over 200%, or 4,863 people in 1890.[37] This rather phenomenal rise in the town's population accompanied other urban developments that opened up new opportunities for employment. By virtue of the town's position on the lake shore, in a direct line between the Appalachian coal fields and the Detroit River, certain geographical advantages obtained. The response to these potential advantages came in 1872 when a railroad connecting Black River harbor with the coalfields of southeastern Ohio was completed. With the revival of Port activities that followed, new opportunities for employment were created and Lorain became a revived and growing village.

The reincorporation of the village into Lorain came in 1874. The Lorain County commissioners renewed the old Charleston charter, which had been granted thirty-eight years before but which had not functioned. However, another post office in Ohio had been given the name of Charleston during the interim, and the postal authorities refused to recognize a second name

[36]Also see Wright, op. cit., pp. 312, 327.
[37]Tenth and Eleventh Censuses of the United States, 1880 and 1890.

of Charleston as a post office. The town then took the same name as the county, which had been named after the province of Lorraine in France.[38]

Areal Extensions of Lorain—The town plan of 1880 included at least eight parcels of land amounting approximately to forty blocks that had been subdivided and added to the town in six years.[39] With two exceptions, these subdivisions were peripheral extensions of the town toward the west, southwest and south around the original townsite of Charleston, which included the Durand Survey and the subsequent extensions already described. For the first time, two small subdivisions four blocks apart appeared along the lake front on the east side of Black River. One addition in 1874 added seven city blocks to the main commercial street, Elyria Avenue (now Broadway). These earlier additions stand out conspicuously on a map showing the lot lines because the lots are much larger in area. Seventy-five to one hundred-foot frontages were the common sizes, but many were well over one hundred feet. Especially is this true of the lots that run normal to the lake shore. Many of those lots were one hundred feet and over in width and three to four hundred feet in depth. These additions added more urban land to the townsite than the total land in the townsite up to 1872. Although the subdivisions were not filled immediately, the steady growth of the town assured their occupance in a few years.

Growth of Transportation—Perhaps the most far-reaching event in the life of Lorain was the extension of the hinterland by the completion of the Lorain branch line of the Cleveland and Tuscarawas Valley Railroad in 1872. The railroad was originally planned and built from Urichsville, Ohio, to Cleveland by a group of Cleveland capitalists. Two years after the main line was finished, the Lorain branch line of thirty-one miles from Lester, Ohio, to the south of Black River was completed. This, Lorain's first railroad, connected the harbor site of Black River with the coal fields of southeastern Ohio. Moreover, it opened up a marketing territory for products that came by boat to Lorain and thereby enlarged the possibilities of the

[38]Wright, op. cit., p. 292.

[39]The following is a list of the subdivisions and the year they were added to the town: Brownell's, 1st, May, 1872; Chamberlain's, Feb., 1873; Gawn's, 1st June, 1873; Brownell's, 2nd, Sept., 1873; Gregg's, 1st, Nov., 1873; Chamberlain, Edison and Mussey, April, 1874; Hogan's, 1st, Nov., 1878; Hogan's, 2nd, Mar., 1880. J. B. Nichols, of the firm of Nichols and Loofburrow, Civil Engineers, Lorain, Ohio.

town. It being one of the first north-south railroad lines to be constructed, the railroad ran transverse to the general direction of Ohio railroads at the time. By means of these rail connections the extent of the Lorain collecting and distributing territory was greatly enlarged. Until 1883 the southern terminus of the railroad was at Urichsville, where it connected with the Pennsylvania Railroad, which served the coal producing fields of western Pennsylvania and the iron-consuming Pittsburgh district.[40] When, in 1880, the Cleveland and Tuscarawas Valley was extended to Wheeling, W. Va., it greatly enlarged the coal-producing area which the road served and provided several other grades of coal in demand at the ports on the Great Lakes. Railroad connections with east-west lines were made at Wheeling with the Baltimore and Ohio; at Massillon, Ohio, with the Pennsylvania; at Sterling, Ohio, with the Erie Railroad; at Medina, Ohio, with the Baltimore and Ohio, and at Grafton, Ohio, with the Cleveland, Columbus and Cincinnati Railroad. and at Elyria, Ohio, with the Lake Shore and Michigan Southern Railroad.[41] These roads provided a network that connected with most of the large centers in the progressive and expending middle western country.

Early in the eighties the New York, Chicago and St. Louis Railway was completed through Lorain. This railroad connected Lorain directly with points west to Chicago and east, along the lake shore to Buffalo.

Because the Lorain and Tuscarawas Valley Railroad was Lorain's first railroad and because the town was anxious to have the line terminate there, the railroad acquired by grant and purchase over a mile of frontage along the west side of the navigable Black River. Included in the property were the point of low land at the very mouth of the river and the rather extensive tracts on the inside of the first two meander curves of the river.

To facilitate the transhipment of coal at Lorain, the Lake Shore and Tuscarawas Valley Railroad built three coal-loading docks and equipped each with a derrick type of loading machinery. Each crane had a large bucket which was filled by hand and conveyed to the hold of the ship. The coal

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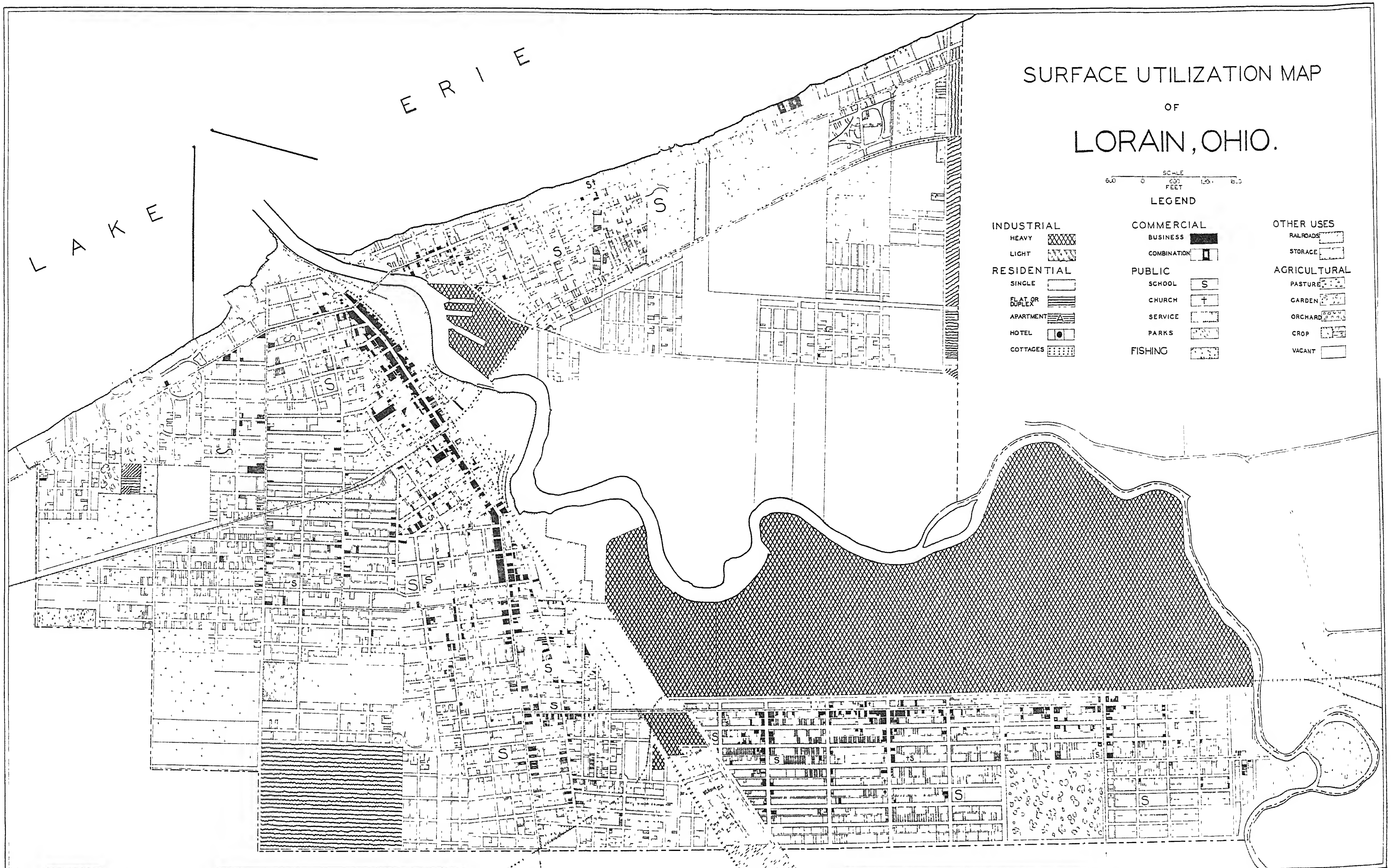
[40]Orth, op. cit., p. 742. Also, Wright, op. cit., pp. 284–5.
[41]Teague, Geo. H. Lorain, a pamphlet published by *The Daily News Democrat*, Lorain, Ohio, p. 67. Also Orth, op. cit., pp 737–743.

docks were located, one at the mouth of the river on the west bank, and the other two just south of the Erie Avenue bridge also on the west bank.[42] Thus the railroad in entering the town from the south paralleled the course of the river, descended on a grade the bluff of the stream to the floodplain and was in immediate contact with ships near the mouth of the river. This eliminated the necessity of ships navigating the rather narrow and crooked river. An ore-unloading dock with two Erie cranes was located at Round House Bend, the second meander in the river. There iron ore from Lake Superior was unloaded from ships, dumped on the docks and transferred to storage bins by "man-powered" wheel barrows. In spite of the crudeness of the machinery thirty to forty thousand tons of iron ore were handled and fifty to sixty thousand tons of coal were loaded from the coal docks yearly.[43]

Transportation on Lake Erie experienced similar changes. The railroads had almost immediately captured the coastwise freight and passenger steamers became obsolete and the water-transported freight business greatly depressed. The dominantly coastwise trade of the former period gave way to the interlake trade in iron ore, coal, stone and pine lumber. When this change was made it gave Lorain an advantage that did not obtain in the coastwise trade. The directness of the route through Lorain for coal northbound and for ore and stone southbound favored the development of the port. Moreover, the loading and unloading facilities near the mouth of Black River were an advantage that saved time and insured greater safety. Lorain was thus enabled to develop in the face of competition with larger Lake Erie ports.

Iron ore in small quantities had been brought to the charcoal furnace at the mouth of Black River as early as 1857; but the ore and coal trade in 1880 dominated the life of Lorain. The harbor which had been all but neglected during the previous period, except for the activity nurtured by the shipbuilding industry, had a sudden awakening and was the focus of activity and development.

[42]Wright, op. cit., p. 328.
[43]Ibid., p. 327.



(171) FIG 5. SURFACE UTILIZATION MAP OF LORAIN, OHIO (172)

PART III. MODERN LANDSCAPE (1894–1934)

A. RECENT GROWTH AND EXTENSION OF LORAIN

1. *Landscape Characteristics*

Lorain, Ohio, is a modern commercial and industrial city of 44,512 people. The city has experienced an extraordinary growth of population from 4,863 in 1890, a gain of 39,649, or an aggregate of 815% in forty years. This increase is almost phenomenal in its proportions and far-reaching in its influence upon the city character. That Lorain developed rapidly and is largely the product of the last four decades is shown by the addition of approximately one hundred subdivisions which increased the areal extent of the city to ten times what it was

TABLE II

Year.. . .	1890	1900	Gain	1910	Gain	1920	Gain	1930	Gain	Agg.Gain
Population.	4,863	16,028	230%	28,863	80%	37,295	32%	44,512	19%	815%

in 1880. Most of the growth has occurred since 1894, when the Johnson Steel Company located its plant in Sheffield Township near Lorain.

The city shows its modernism by the relatively new residential sections where present-day architectural styles prevail; by the broad streets and roomy plan; by the long, drawn-out commercial core; by the absence of a congested, squalid tenement district, so characteristic of the older industrial cities; and by the obvious effects of building regulations and city planning that are manifest in the landscape. So recent has been the growth and so numerous and well regulated have been the city's extensions, that it is difficult to locate evidences of former periods. Included in the present corporate limits are 6,335 acres of land of which area about three-fourths is occupied.

Present-day Lorain is a city of churches and schools, especially parochial schools, of foreign club houses, and of Americanization and other social settlement houses. These cultural forms show the population to be a heterogeneous one of many ethnic groups. The numerous combination business and residential houses, and the stores with the names of the business displayed in foreign languages suggest that a high percentage of the population is foreign and that the foreign influence dominates certain sections of the city. More than

50% of the population is classified as foreign, including those of foreign birth and those native born of foreign parents.

Although the city is divided into East Lorain and West Lorain by the river, and separated from South Lorain by distance and inconvenience; and although racial groups are separated among themselves along ethnic lines and there is a general contempt on the part of the American for living in the "foreign" sections, the city is unified politically. This political unity dates from 1895, shortly after the Johnson Steel Company located at Lorain. The officials of the steel company agreed that their property should be taken into the city provided the city voted bonds to widen the river and build a turning basin for ships. The bond issue carried, the work of improving the river started and the corporate limits subsequently extended to include all of South Lorain. By the addition of the steel plant property and the South Lorain townsite the taxable property valuations were greatly increased. At present there is a well developed allegiance to and respect for the city government located in West Lorain.

Bifunctional Character—The evidences of the bi-functional character of Lorain are many. Piles of red iron ore and grey limestone in storage, the parallel railroad tracks of the car storage yards, switching locomotives, and the unloading machinery with capacities far in excess of local plant consumption, all bespeak the break-of-bulk function of Lorain; while the manufacturing establishments, with their employees filing in and out as they punch the time clock, are reliable evidences of the local industrial development.

By the heavy character of the materials used, by the specialized manner in which the transfer of freight is accomplished, by the size and type of the manufacturing, one sees that Lorain has developed into a highly specialized city in the performance of the bi-functional activities.

As already stated, the first opportunity for the growth of Lorain was initiated by the transhipping trade (Table IV). Although this trade, especially in coal and iron ore, has increased enormously since 1890, the manufacturing industries have developed to a point where they are much more important than the break-of-bulk activities. Lorain still retains its reputation over the Great Lakes as an important transhipping port, by virtue of an increase in coal and ore tonnages at the expense of some of the other lower lake cities. However,

the industrial stamp has been placed upon Lorain by the development of industrial plants which reduce at the point of transfer some of the raw materials hitherto shipped through the city. In a normal year one-half of the total tonnage of ore received at Lorain is reduced in the local plant of the National Tube Company. During the previous period exports from Lorain far exceeded the receipts. Due largely to local plant consumption, this condition has been reversed and the

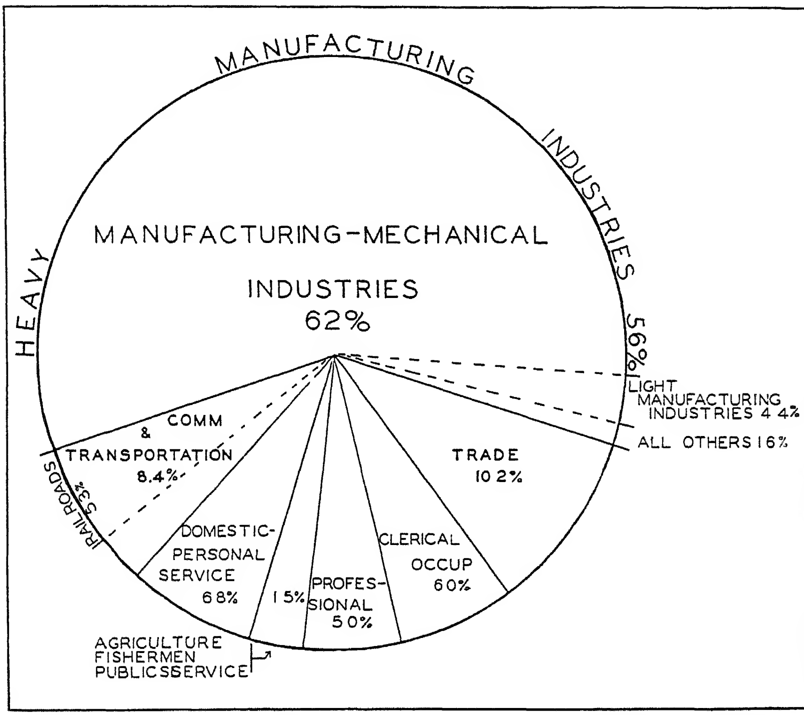


FIG. 6. Occupational distribution of the population of Lorain (U. S. Census).

imports of iron ore and limestone for both consumption and transhipment now far surpass outgoing freight which consists principally of coal.

Local benefits from industrial developments are many more than those derived from the transhipping trade. This is more true today than it was in the past because most of the transfer of products is now done by machinery directly and in one operation. Thus the number of men employed in making the transfer from water to land has been greatly reduced.

Where once hundreds of men were employed in unloading cargoes of ore and transferring the ore to stock piles, fifty times as much ore is now unloaded by twenty or thirty men operating machines. Most of the ore is transferred directly to trains instead of it being stored as formerly. Thus the tendency has been increasingly to reduce the benefits that accrue to the town from its break-of-bulk activities. On the other hand, factories employ thousands of workmen and the factories become taxable property helping to support other urban institutions.

In the heavy industries alone there are employed in Lorain 9,160 people, while employed on all steam railroads there are 938 people and in all forms of tranportations only 1,367 people.[1] Of the number employed on railroads only a small proportion is engaged in the actual transfer of freight, while the number of employees assigned to the heavy industries is definitely engaged in manufacturing local products. Thus the land utilization and occupational analyses have proved to be complementary indices of the relative importance of manufactural and transhipping functions of Lorain.

2. *The Present Plan*

Evolution of the Urban Plan—The plan of Lorain is but the modernized and expanded outgrowth of the city in the previous period. This expansion has been accomplished by the addition of many small townsite subdivisions always attached to the outside of the main urban nucleus. Each urban patch so added does not always fit closely into the previous additions, thus giving variety to the present plan. The present areal extension is 6,335 acres of land within the city limits available for residence, industry, transportation, retail stores, etc.[2]

Adhering closely to the lake shore and to the bluffs of Black River the city has been drawn out into a peculiar shape. Two arms of city development extend well beyond the city limits, one eastward toward Cleveland and another westward along the lake shore (Fig. 5). This development also parallels the principal highway from Cleveland west through Lorain to other cities along the lake shore. The main body of the city is almost at right angles to these arms and parallels

[1]Fifteenth Census of United States. Ohio Supplement on Composition and Character of the Population. Table 25.

[2]Lorain, the City. Op. cit., p. 8.

the Black River Valley until the valley turns eastward. Here the city's axial line turns eastward to parallel the bluffs of Black River. This latter elongation of the city plan has come about through the location of the vast property of the National Tube Company on the river and the large residential section associated with the plant. Thus the city is divided into three parts or sections which are popularly known as East Lorain, West Lorain (or just Lorain) and South Lorain.

East Lorain—East Lorain is in areal extent about one-sixth of the total occupied surface of the whole city. It is essentially a residential overflow across the river from the main city on the west side, since its principal growth has been after the county bridge was constructed across the Black River gorge just two blocks upstream from its mouth. This bridge erected in 1898 connects the two ends of Erie Avenue at the same level and is the transportational thread that holds East Lorain. Except the Nickel Plate railroad bridge, there is no other bridge that crosses the gorge for a distance of six miles upstream. This dependence upon one bridge has prevented East Lorain from developing and expanding over much of the space available for occupation. Except for the long arm that parallels Erie Avenue, this section of Lorain is considerably condensed around the end of the bridge and the plant of the American Shipbuilding Company. For a person living in East Lorain to go to the steel plant one half mile straight across the Black River gorge, it would be necessary to cross the river near the mouth, then go through West and South Lorain, a distance of approximately seven to eight miles.

The street pattern of East Lorain is a simple rectangular one, with the Main Erie Avenue running parallel to the Lake Erie shoreline and the other group of streets at right angles to it. Where the townsite projects westward on the narrow point of land between the lake shore and the first meander in Black River, there are short cross streets with dead ends. For a distance of almost two miles there is no cross street between Erie Avenue and the lake shore. Here Erie Avenue runs within four hundred feet of the lake bluff, and since the strip is not deep enough for another block, the other set of streets is absent and the lots are therefore very deep. Near the mouth of the Black River the lakeshore trends away from Erie Avenue and there is room for one street which parallels Erie Avenue.

Another main street and road which skirts the bluffs of Black River for a distance and continues around the southern edge of East Lorain connects with the ends of the cross streets, thus giving an outlet to the streets that would ordinarily develop into dead ends.

West Lorain—West Lorain is the principal part of the city, having the main commercial-retail stem and constituting approximately three-fifths of the occupied surface of the entire city. Moreover, West Lorain shows much more independence in its development pattern than does East Lorain. It has the main residential sections, most of the schools, the principal churches, and the city administrative offices.

The main outline is radial in plan having inherited these characteristics from former surveys. From a point near Black River one street, Elyria Avenue, runs southeast parallel to the course of Black River. Another, Oberlin Avenue, extends southward, and a third is West Erie Avenue extending southwest parallel to the lake shore. There is a slight crook in Erie Avenue to gain a right angle crossing of the river gorge, otherwise the street would run in a straight line through the entire city.

As these main streets radiate from the center, between Oberlin Avenue and Broadway, the radial pattern is further perfected by the introduction, at later periods and as the town expanded, of other streets which trend in directions between southeast and south. These streets begin only after the divergence has been sufficient to allow the introduction of north-south streets which would separate blocks three to four hundred feet long. Because of this radial pattern of streets and the successive divergence of streets, city blocks may get successively longer toward the south until the introduction of another north-south street shortens the block. A few subdivisions with rectangular lines have been laid out but these are conspicuous misfits in the radial scheme because the streets do not join other streets directly but offset them. In the interests of efficiency the city has had to condemn property in order to bring about proper street connections. On the other hand, the radial pattern has led to an overburdening of a few through streets which have to carry most of the city traffic as it nears the downtown section. Only four converging streets in West Lorain run without being interrupted from the outer edge of the occupied townsite to the downtown part of the city, while there are fourteen other streets that run a portion of the way.

The streets which run at right angles to a radiating series would theoretically have to be curved. But in order to get straight frontages along the block, the streets are resolved into angular patterns. That is, they run straight for a distance then turn at a low angle to run straight again before turning still another time. Near the center of town the street turns are more frequent than in the outer, newer portions. Therefore in the downtown section there are more short, oddly-shaped blocks than in the outer, newer sections where the divergence of the streets has led to less frequent turns in the street, hence a more nearly perfect retangular pattern of blocks.

Between Oberlin Avenue and West Erie Avenue, all subdivisions have been laid out in accordance with compass directions. One group of streets runs north-south parallel to Oberlin Avenue and another east-west at right angles to it. Blocks are rectangular in shape and reasonably uniform in size.

Between West Erie Avenue and the lake-shore is a strip of land about a block and half wide where the subdivisions have been planned so that the blocks run parallel to the lake shore. This scheme permits frontages along Erie Avenue and Lake Erie the most desirable features.

South Lorain—South Lorain is that section of the city extending from the Sheffield township line west to the Black River on the east and is as orderly in plan as West Lorain is disorderly. The entire section, constituting approximately 2,000 acres of land embracing all of South Lorain and a small section west of the B. & O. R. R. tracks, is encompassed by the River on the North and East. This rather sudden addition represents Lorain's greatest growth and corporate extension. It dates from the time when the Johnson Steel company, predecessor of the National Tube Company, located there in 1894. It was really a removal of a part of the Johnson's plant from Johnstown, Pennsylvania. Company officials desired a location where iron ore could be economically reduced, steel made and steel rails manufactured.

The establishment of the steel plant at Lorain was a capitalistic undertaking and resulted in an almost cataclysmic change of the landscape from a semi-primitive natural state to that of industrial complexity. Without divulging their plans the Johnson Company's representatives working incognito obtained an option on a block of land 4,000 acres in extent.

Most of the land was located in Sheffield Township and along the south bank of the Black River, although a small tract on the north side of the river was also acquired. These lands at that time were entirely outside of the city limits or urbanized portions of Lorain.

Plans of the company were subsequently announced, options on the lands closed, hundreds of men were put to work cutting the trees, sawing the logs, and clearing the rubbish. The block of land on the south side of the river was divided into two parts. A block of 1700 acres lying adjacent to the river was reserved for industrial purposes, and another portion consisting of 2,300 acres and adjoining the plant property on the south was reserved as a residential townsite for plant employees. A subsidiary company, the Sheffield Land Company, was organized to develop the residential townsite. The plant layout was planned in accordance with the cardinal points of the compass and the rectangular pattern of the streets and avenues was similarly oriented. In a short time the plant site appeared absolutely clear of all forest growth and, in the townsite, the streets appeared as avenues without forests.

According to the plan of the Sheffield Land Company a townsite of approximately sixty blocks was laid out. Land was plentiful and (the Company had paid an average of only $30. per acre for it), as a consequence officials were generous in the amount of land allotted to streets, parks, and the lots in every block. Streets were surveyed 80 to 100 feet wide, while standard size lots were 50 feet in width by 120 to 150 feet in depth. Blocks were cleared of the forest cover, lots were sold, houses were erected by the company, a sewer system installed, sidewalks were laid, curbings installed, streets improved and a new town was born. Now the main street, East 28th Street, runs in front of the steel plant property. Seven other streets lying south of 28th Street run east-west parallel to it. Cross streets run north-south from 28th Street to 36th Street, the corporate limts of the city. Thus the blocks contained in the addition are long, but uniform and orderly.

This capitalistic enterprise, comprising a large industrial plant and an adjoining residential townsite covering approximately 3,000 acres of land, was planned and partly built before there was any production or profit made from manufacturing. The whole South Lorain addition was a typical large-scale

capitalistic venture conceived, planned, and built upon the knowledge of the advantages such a location offered.

Site Advantages—The steel plant site was an elevated lake plain of remarkable levelness lying fifty to sixty feet above Black River. The descent to the river, or river bottom, was over a steep cliff. This factory site overlooking the Black River gorge a quarter of a mile in width was an excellent place for a steel plant. Black River was navigable for three and a half miles upstream which placed the head of navigation well within the boundary lines of the Johnson Company's property and, for twenty years, iron ore had been brought to Lorain and transhipped to the furnaces of the interior.

A curved ore dock was constructed on the outside curve in the river to take advantage of the deep water where the river undercuts the bluff. Morover, the river at this point cuts farthest southward into plant property thus placing the ore nearest to the proposed plant site.

Covering the surface of the level plant site was a thin layer of compact clay soil four to seven feet thick that offered a good base for railway tracks and superficial structures. Directly under the soil mantle was the Ohio shale, a geological formation that has a capacity of standing almost vertical when exposed. Yet the shale was thin-bedded and easily broken so that excavating for foundations was relatively easy. This shale formation was good solid foundation material for the heavy mechanical installations necessary in a steel plant.

The steel plant was first planned and designed to produce steel street car rails (girder rails) and standard railroad rails. In 1907 the plant shared "with Steelton the work of making all the rails and most of the equipment for the street railways of the United States, and both of these plants have taken a part in foreign trade in this line of work."[3]

The site also offered excellent facilities for dumping factory refuse. This is an important item in the location of a steel plant because of the bulky nature and great volume of slag, cinders and ashes, that come from the different units. Hot slag from the blast furnaces was dumped over the bluffs of Black River to the flood plain. And although the steel plant has been dumping slag, ashes, and other factory refuse over this bluff since 1895 and has built two immense slag piles, there

[3]Campbell, Harry H. The Manufacture and Properties of Iron and Steel, Fourth edition, third impression, 1907. McGraw-Hill Book Company, New York.

continues to be ample space left on company property for future operations. Increase in the use of slag for road building material and in concrete construction work has greatly retarded the accumulation of slag on the dumps.

Water is a necessity in a steel plant. Great quantities are used to cool and help preserve the blast furnace linings, to generate steam, to wash the blast furnace gases, to quench the coke from the by-product ovens, and many other uses. To supply this need, the Johnson Company created a reservoir by damming a small ravine that entered Black River from the south. The constant replenishment of water to the reservoir by an evenly distributed rainfall sufficed for plant needs many years. But more recently a short tunnel has been driven from the main power unit to Black River where water for plant use is now obtained.

While the major outlines of Lorain are very materially influenced by the two natural features, the Lake Erie shoreline and Black River, the minor irregularities in the town plan have been influenced by a great number of forces. Plant locations, dependence upon a crossing of Black River, inherited plan, compass directions, Lake Erie shoreline and personal choice have all been potent influences in forming the landscape pattern of Lorain.

B. ELEMENTS OF THE CULTURAL LANDSCAPE

1. *Heavy Industrial*

National Tube Company—The enormous plant of the National Tube Company, subsidiary of the United States Steel Corporation, is today by far the largest single industrial form in the cultural landscape of modern Lorain. Covering 1442 acres of land, this plant with all of its manufacturing and supplementary units, ore docks, ore storage yards, and pipe storage yards, occupies over 95% of the surface classified as heavy industrial and one-fifth of the total surface within the city limits of Lorain. The entire plant is set apart from the residential and commercial sections of the city by a high iron fence which completely surrounds the land exposed side of the plant. Access to the plant is gained through four large gates, three on the south side and one on the west side, which lead to different manufacturing units.

The National Tube Company's property is located at the head of navigation on Black River, three and one-half miles

from its mouth, and extends up-stream for a distance of three and one-half miles more. The property has seven miles of water frontage and is well protected on the river side by the gorge.

Within this great inclosure are located, an ore dock, a by-product coke plant, one bar mill, a shape mill, a large rock crusher, five blast furnaces, two Bessemer converters, twelve open hearth furnaces, three blooming mills, five skelp mills,

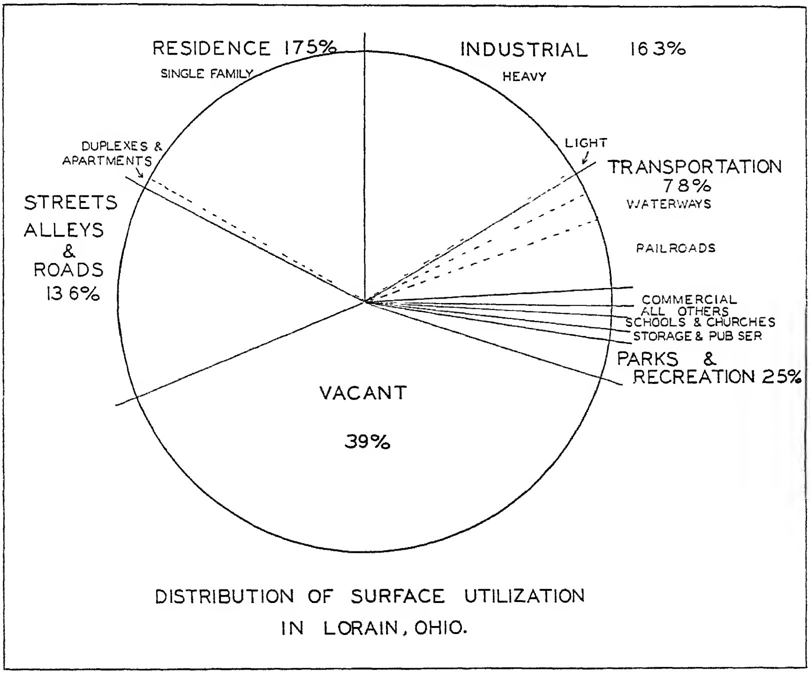


FIG. 7. Distribution of urban land utilization. Included is all the land in the present corporate limits of Lorain, Ohio. Compare with Fig. 5.

six butt-weld mills, and three seamless pipe mills (Table III). In addition, there are many smaller auxiliary units such as machine shops, paint shops, power units, carpenter shops, laboratories, electrical shops and chemical units. Three systems of transportation are used in the plant. The standard-gauge plant railroad, the Lake Terminal, handles all freight within company property. This railroad has a complete system of trackage to all the plant units and connects with the four railroads serving the plant from the outside. A narrow-gauge railroad system for the purpose of hauling the heavy materials

from one plant unit to another ties the several units together. A highly specialized electrical system is used in several plant units. The system includes the electrical machinery for conveying the materials and charging the open hearth furnaces, electrical conveyors and hoists for handling the retorts of molten iron and steel, etc.

Employing in normal times 5,000 to 7,000 men, this plant supports directly 20,000 to 30,000 people which is between one-half and two-thirds of the total population of Lorain.[4] However, 1,500 or more including a few of the administrative officials live outside of Lorain.[5] Many live in Elyria, eight miles south and in the adjoining rural sections near Lorain. These employees commute daily by interurban or by automobile. Indirectly the steel plant influence is much more widely felt because of the dependence of business concerns and professional people upon these plant employees.

The steel plant is really made up of several manufacturing units that are more or less complete within themselves. However, the units are so closely associated in ground plan and complementary in operation that the manufacturing processes may be continuous throughout the plant to form finished products such as pipe, rails and tubes, or they may be terminated at several points to produce such semi-manufactured products as billets, blooms, ingots, skelp, bars, etc. Manufacturing processes are progressively more advanced from the iron ore storage yard on the west to the steel pipe storage yards on the east, about two miles distant. By-products originate at many points in the plant. Some are finished and go directly to the markets for consumption while others are processed and become the raw mateials for other manufacturing concerns. The processing of these by-products to render them marketable is done in the many small plant units. Ammonium sulphate, ammonia, coal tar, crude naphtha, naphthalene, phenol, toluol and slag are the end products of the local plant units and the most important by-products of the National Tube Company's plant. The local plant is independent to the extent of manufacturing pipe, rails and tubes, and is supplementary to other outside manufacturing plants in the manufacture of most of its remaining products.

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[4]No exact figures on the total population affected by this plant are available. However, the *Lorain Journal's* industrial series (issue Dec. 10, 1928) states that "60% of population of city attributed to National Tube Co. Plant."

[5]Statement of Secretary of Lorain Chamber of Commerce.

The Plant Lay-Out—The arrangement of the units in ground plan is designed to give maximum efficiency. The curved iron-ore dock, 2400 feet in length and easily accommodating three 600-foot ore boats, is located where the river cuts against the bluff and into the property of the National Tube Company. Four modern clam-shell unloaders with a capacity of a million tons of ore each in a season transfer the ore from the boat to the dock. Three ore bridges then place the ore in storage piles.

TABLE III[6]

No. of Plant Units	Types of Units	Annual Capacity of Units	Product of Units
1	Ore unloading dock	4,000,000 tons	Ore
1	Coke plant 208, By-product ovens	1,213,000 tons	Coke
5	Blast furnaces	1,170,000 tons	Pig Iron
2	Bessemer converters . .	600,000 tons	Steel Ingots
12	Open hearth furnaces . .	900,000 tons	Steel Ingots
3	Blooming mills	1,245,000 tons	Ingots
1	Shape mill	150,000 tons	Steel Rounds
1	Bar mill	500,000 tons	Steel Rounds
5	Skelp mills: Includes 13-inch and 14-inch continuous mills, 24-inch reversing mill, 48-inch universal mill and 90-inch plate mill with range of from 1 inch to 78 inches in width..	465,000 tons	Skelp
6	Butt weld mills . . .	190,000 tons	⅛ in. to 3 in. pipe
3	Lap weld mills..	130,000 tons	2 in. to 23 in. pipe
3	Seamless mills	350,000 tons	2 in. to 24 in. seamless pipe

Total pipe capacity, 670,000 tons annually.

Limestone is handled in much the same way except most of the "stone" boats are equipped with self-unloading machinery. (Figs. 8 and 9, page 189).

Next in plan are the five blast furnaces located as closely to the ore storage yard as possible to eliminate long hauls and facilitate the charging of the blast furnace. Coke from the coke plant is conveyed in skip cars a few hundred feet west and limestone and iron ore move a similar distance east which completes the blast furnace charge. In the power unit next adjacent the air is heated, compressed and conveyed to the blast furnaces. The closeness of the power unit insures a

[6]From "Your visit with the National" pamphlet of National Tube Company.

minimum loss of heat in delivering the blast to the furnace. The very high temperatures necessary to maintain iron and steel in a molten state or workable condition, requires a tremendous amount of fuel. Therefore every precaution is taken in the modern plant to prevent any greater loss of heat than is necessary. Two Bessemer converters and 12 open hearth furnaces manufacture steel out of the blast furnace iron and are placed next eastward from the furnaces. Without the loss of any more heat than is required to permit the steel to solidify, the steel ingots are reheated and run through the rolling mills. These buildings are long, one-story, spacious structures with ample room overhead for an electric conveyor system. The manufacturing process may terminate at this point to form the semi-manufactured steel products—billets, blooms, rounds, etc. But if pipe is to be manufactured the process continues through a long, continuous set of buildings, housing the skelp and pipe mills.

Raw Materials—In a modern steel plant such as that of the National Tube Company, there is a surprisingly large number of raw materials used in varying quantities. However, coke, iron ore, and limestone are the materials of greatest bulk and are used in the greatest quantities. Even with these primary minerals there is often a variation in locational origin because of a variation in their chemical or physical character. For example, the different ore stock piles represent different grades of ore that often originate in widely separated localities. The local coke plant consumes two grades of coal, one from Connelsville, Pennsylvania, district and another from Gary, West Virginia district. One is a high-volatile, low fixed-carbon coal and the other is a low-volatile, high fixed-carbon coal. Because there is no dependable local supply of natural gas and because the company must have a gas of a certain b. t. u. rating, it is necessary to mix the two kinds of coal even at greater freight cost to get the quality of gas desired for use in the steel furnaces.

Besides the primary minerals there are used in the steel plant large quantities of dolomite, refractory magnesite, fuel oil, scrap iron, three or four grades of brick and tile, sulphuric acid, several ferro-alloys—speigeleissen, aluminum, ferro-silicon, ferrochrome, ferro-manganese, zinc shingles, and rust prevention materials.

There are many other materials used in smaller quantities.

In this list are represented may raw materials that are the finished products of numerous other factories located throughout the country.[7] So that in the modern steel plant there is an intricate system of inter-factory dependencies. And while the total quantity of these materials is not so great as that of coal, iron ore and limestone, the aggregate amount consumed is surprisingly large.

Economic Aspects

In the location of a steel plant at the point where there is a break in the bulky freight several economies are possible. Especially is this true when the plant is a unit of a larger corporation and performs a transhipping service for member plants of the interior. The National Tube Company at Lorain performs such a service for the plants of northern Ohio and the Pittsburgh district. Enough iron ore and fluxing limestone must be imported during the navigation season and held in reserve to keep both the local and interior furnaces going. By unloading the raw materials with plant equipment and storing on plant property, there is an aggregate saving of eight to thirty-three cents per ton gross on ore and thirteen to twenty-three cents on limestone or dolomite.[8] When ore is held in storage the cost increases rapidly. Therefore, there is a greater tendency either to make immediate and direct ore shipments or to store the ore in stock piles on company property.

The two grades of coal, one from the Connellsville district and the other from the Pocahontas field, are brought to Lorain at a freight cost of $1.84 and $2.64 per ton respectively. When processed these two tons of coal will yield one and one half tons of coke, 18,000–20,000 cubic feet of gas, and many valuable by-products. The ton and a half of coke thus produced is sufficient to reduce three tons of 50% iron ore in the presence of two-thirds of a ton of fluxing limestone. The minimum

[7]A further treatment concerning locational origin and quantity movements of these raw materials will be found under the Transportational section.

[8]The port charges are:

	Ore	Dolomite
From rail of vessel to car for direct shipment	8 cents	13 cents
From rail of vessel to dock	20 cents	...
From dock to car	13 cents	13 cents
Transfer from dock to storage pile	12 cents	6 cents
Reloading from dock or storage to car	13 cents	10 cents
Monthly storage charge	1 cent	1½ cents

Ports of Sandusky, Huron, and Lorain, Ohio, Lake Series No. 8, Corps of Engineers, United States Army, pp. 131–32

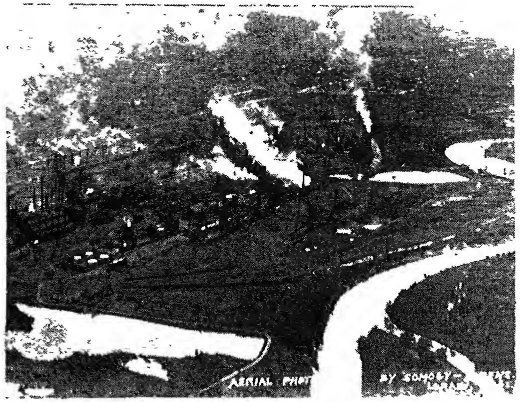
cost of handling and shipping the three and two-thirds tons of raw materials to the furnaces in the Pittsburgh district is $4.51 (8 cents handling charge and $1.15 per gross ton freight).[9] Since the cost of shipping the coal is three cents less than the cost of shipping the raw materials to the interior, the by-products may be obtained for the cost of the coal at the mine mouth, plus the cost of extraction. When the coal mines are operated by the consuming company further economic advantages develop.

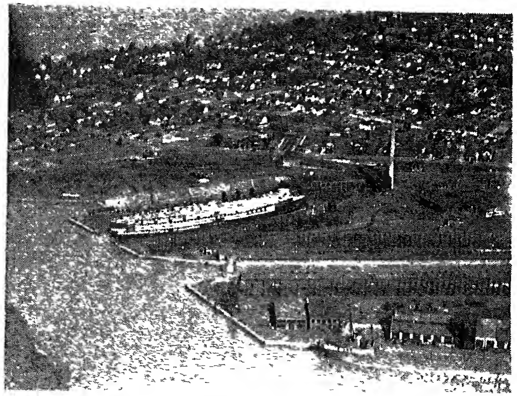
American Shipbuilding Company—The second largest unit in the heavy industries of Lorain is the plant of the American Shipbuilding Company. Occupying forty-three acres of urban land on the east flood-plain of Black River, the plant covers less than 1% of the total area of Lorain and only 3% of that of the National Tube Company alone. The property extends from the river's east edge to the east bluff of Black River, and from the tracks of the Nickel Plate railroad northward to within 2,000 feet of the mouth of the stream. Dredged out of the soft marshy floodplain alluvium are two launching slips over 400 feet long and one dry dock 747 feet in length which is said to be "the largest on fresh water."[10] The southward curve of the river bank made it possible for the launching and dry dock to be dredged almost in line with the lower course of the river, thus facilitating the berthing of ships entering for repairs or launching new ships going out of the river. Construction berths for six new vessels and ten vessels in repair at one time is the maximum capacity of the plant. To effect repairs to marine craft the plant equipment includes: a machine shop, boiler shop, punch shop, a pipe shop, tin and electric shop, joiner shop and two large blacksmith shops. Ample facilities are provided for the building and repairing of the largest ships on the Great Lakes. (Fig. 10).

This company employes anywhere from 50 to 1,000 men, since the work is of a highly seasonal nature and subject to oscillations. The early spring is the outfitting and general repair season for ships in preparation for the opening of the navigation. Throughout the navigation season, the shipyards are kept busy in servicing, repairing and building new craft. One service launch and four scows used in making repairs to

[9]Transportation on Great Lakes, Transportation Series No. 1 (Revised edition, 1930), Supt. of Documents, p. 282.

[10]Wright, op. cit., p. 322.





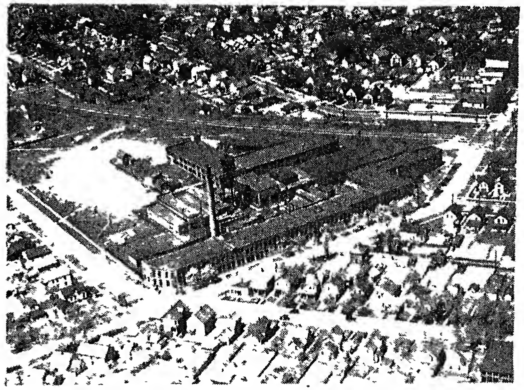


FIG. 8 (upper left). Plant of the National Tube Co. Looking east over the entire plant layout.

FIG. 10 (lower left). Plant of the American Shipbuilding Co., on the river flood plain. The river bluff marks the beginning of residential East Lorain.

FIG. 9 (upper right) Aeroplane view looking southwestward. In the middle ground are the open hearth furnaces, the by-products coke ovens and the blast furnaces.

FIG. 11 (lower right). Factory of the American Stove Co., near the Nickel Plate R. R. tracks in West Lorain.

Photo by Somogy-Lorens, Lorain

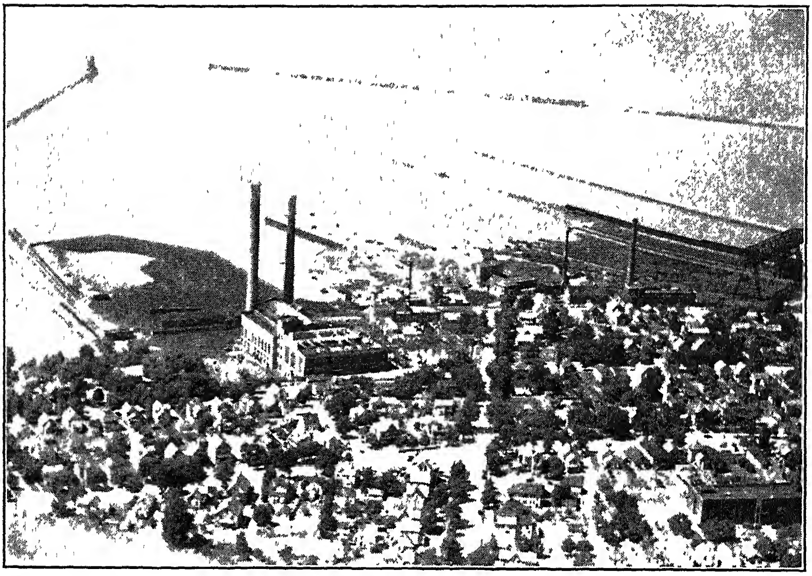


Photo by Somogy-Lorens

FIG. 12. Aeroplane view looking north and showing the outer harbor, a portion of the inner harbor, Ohio Public Service Generating Plant, the Ice Plant, the Lorain Waterworks and the B. and O. ore bridge.

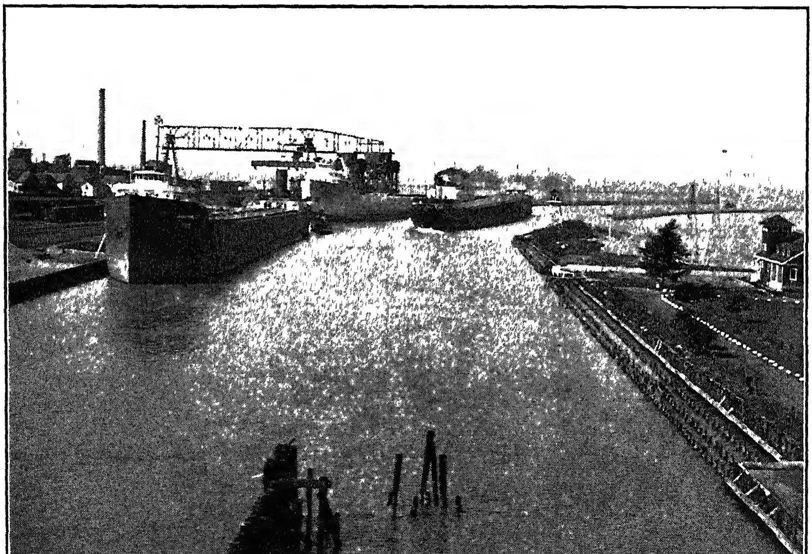


Photo by Michael Studio

FIG. 13. Inner harbor of Lorain, looking north. Ore docks, storage yard and tracks of the Baltimore and Ohio Railroad

boats in the harbor are additional equipment that are confined to the harbor.

The era of steel shipbuilding in the Lorain shipyards did not follow immediately the abandonment of wooden ship construction. Steel shipbuilding is a capitalistic enterprise and did not begin in Lorain until 1897 when the Cleveland Shipbuilding Company was formed. This expansion is related to the expansion in the ore carrying trade at the same time. Ore, limestone and coal boats in increasing size and numbers were needed in this trade and the Lorain shipyards increased in areal extent and functional importance as a consequence. The depth of Black River and the nearness to the mouth have enabled this company to build some of the largest vessels on fresh water and for all sizes of ships to enter Lorain harbor for repairs.[11]

The Thaw Shovel Plant—Based upon areal extent of urban land used, the number of factory workers employed, size of the factory buildings and plant equipment, and the value of the products produced, the Thaw Shovel Company and its affiliate, the Lorain Castings Company, are the third most important of the heavy industries of Lorain. The two plants occupy a level, lake plain site between the South Lorain townsite and the Baltimore and Ohio right-of-way. The plant includes five large brick structures and a spacious storage yard around the factory buildings for reserve equipment and finished steam, gas and electric shovels, cranes and other mining and excavating machinery. Together with the supplementary plant of the Lorain Castings Company, which occupies a separate building and grounds just across the Baltimore and Ohio Railroad tracks, the factory and storage yard cover almost exactly 1% of the heavy industrial land of Lorain. Employing three to four hundred men, this factory has been stimulated by the general acceptance of its products in mining, road building, construction work, quarries, clay pits and in other similar work.

The factory is somewhat more than an assembling plant though that work is the principal phase of factory employment. Although some of the shovel parts are made in its supplementary

[11]Up to 1913, 129 ships had been constructed classified as follows: freighters, 109; oil steamers, 2; oil barges, 7; tugs, 9; salvage lighter, 1; mountain summer resort catamaran, 1. Of the 109 freighters the tonnages were: 6, 12,000 tons; 11, 10,000 tons; 1, 9,000–10,000 tons; 2, 8,000–9,000 tons; 15, 7,000–8,000 tons; 40, 6,000–7,000 tons; 8, 5,000–6,000 tons; 36, under 5,000 tons. Source: Wright, op. cit., p. 323; also in Annual Reports Chief of Army Engineers, U. S. Army.

plant at Lorain, many of the parts come from other widely scattered factories to be assembled into the finished product in this plant. Waukesha motors, and iron and steel shovel parts from Chicago, St. Louis, Pittsburgh, Erie, all find the way into the finished "Lorain" shovel.

The location of this industry at Lorain is related to its history, while the areal extent of the factory and industrial magnitude of the business are explained by the specialized nature of the finished product, which is now protected by several patents. In 1898 a retired captain of an ore boat started manufacturing in a small plant a shovel for removing iron ore on the dock.[12] This device had been developed and patented by Captain Thaw and was used many years on the ore docks of the lower lake ports. Subsequent development of the ore bridge replaced the shovel for the removal of ore, but its use was adapted in a large way to all kinds of excavation work and the plant expanded to its present proportions. This factory differs markedly from that of the National Tube plant in the manner in which the cultural landscape has been affected. By the smaller size and gradual growth, the Thaw Shovel Company has been absorbed into the expanding urban landscape without greatly altering it, while the plant of the National Tube Company not only metamorphosed the surface landscape but greatly changed the plan of Lorain.

Because of the specialized nature of the shovel, its high value in relation to bulk, and the varied industries in which it is used, markets for the "Lorain" product are all over the world. Although these shovels are shipped to England, France, Spain, Italy, Cuba, Chile, Peru, New Zealand, Mexico, Tasmania and Canada, this country is the greatest consumer. The central position of Lorain with respect to the center of population in this country together with the excellent railroad facilities for shipping in almost any direction give Lorain an excellent market advantage.

Other Establishments—Several other industries have contributed a proportional share toward the expansion and now help to sustain Lorain as an industrial city. And it is only in relation to other larger industries that they are of lesser importance. But because they occupy less urban land, their factory buildings are much smaller, they employ fewer people and their finished products have less value than the enter-

[12]Industrial Survey, *Lorain Journal*, issue of May 5, 1928.

prises already considered, these industries must here be considered en masse.

The National Stove factory, the American Crucible Products plant, the Steel Stamping works and the Brunk Machine and Forging Shops conclude the list of the heavy industries of Lorain.[13] (Fig. 11). The first three have factory locations along railroad sidings, while the last maintains a plant which fronts on Broadway, the principal commercial-retail street. All combined, these four industries occupy only ten acres of land surface, which is slightly more than .5% of the total surface devoted to heavy industrial. The National Stove Works occupies a three-story, box-shaped factory building with four times as much floor space as all three others combined. This plant has enough floor space and equipment for 250 men working to complete 300 stoves a day.[14]

In the plant location pattern of the heavy industries in Lorain two important influences stand out, the navigable Black River and the railroads. The former makes possible an industry based upon marine activities and enables raw materials for factory consumption to be imported, while in the latter case the railroads offer shipping facilities.

2. *Light Industries*

The light industrial establishments in the Lorain landscape are small and inconspicuous when compared with the ponderous character of the heavy industrial plants. For this reason they are likely to be overlooked or relegated to a place not commensurate with their actual importance in the life of Lorain. Nevertheless, there are twenty-four establishments so classified here. The light industries are of three types: the factory, employing many workers in one building but occupying relatively small ground space; the small individual establishments, but important because of their aggregate number; and the public utility generating and manufacturing plants. There are two establishments manufacturing clothing that belong to the first

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[13]The American Crucible Products employs 30 to 40 skilled workmen in making bronze castings and bearings, babbit metal, faucets, etc. The Steel Stamping manufacturers metal toys (telephones, automobiles, wagons, etc.), sink strainers, mail boxes, milk bottle holders, map sticks, etc. Markets for these articles are in the 10 and 25-cent chain stores throughout the country. Employment in this plant is highly seasonal because of the seasonal nature of the market. However, fifty to sixty men are employed during the months preceding the Christmas season. The Brunk Machine and Forgings Company does custom machine work.

[14]This concern is, perhaps, best known through its products, the Direct Action Stove and the Lorain Oven Regulator, which were developed in this plant.

class; twelve bakeries, and thirteen dairies and creameries belonging to the second group; and the electric generating station and ice plant are in the third class.

All light industries combined employ approximately 10% of the total number employed in heavy industries, and only 13% of the number employed at the National Tube Company's plant alone.[15] On the other hand, the total value of the manufactured products is relatively high. These industries occupy a place in the landscape, and help to lend variety to the type of employment.

Clothing Industries—The large factory of Richmond Brothers now the Goodall Company, manufacturers of men's ready-to-wear clothes and the smaller factory of Printz-Biederman, manufacturer of woman's apparel conclude the list of factories in this group. The former occupies a large five-story box-shaped structure formerly a wholesale house, while the latter is housed in a modern brick factory building.

These two plants together employ 65% of the total number of wage earners in the light industrial group. The Richmond Brothers factory employs 400 women and 50 men, almost exactly 50%. Both of these establishments are specialized branches of main factories located in Cleveland. In each case the materials from which clothing is made are cut in the main factory and sent to Lorain to be assembled. This policy of dividing the work together with the recent establishment of the branch factories shows them to be the result of expansion growth in the parent concern.

Thus the location of these factories in Lorain reflects three advantages: (1) the closeness of the branch to the main factory and the relative ease with which the piece-goods may be transported from Cleveland twenty-five miles; (2) the surplus of women workers in a city dominated by the heavy industries; and (3) the lower tax rate of 21.6 mills in Lorain as compared with 27.6 mills in Cleveland. These two factories draw their labor supply from the homes of other industrial workers and are, in that respect, dependent upon other industries.

Baking Establishments—Lorain at one time had nineteen bakeries, mostly small individually owned establishments, but today the industry has contracted until there are only twelve

[15]In computing these percentage figures compiled from the Census of U. S. 1930 were used. In the three classes of light industries there are 934 employees and 7,302 workers in blast furnaces and rolling mills. Table 25, Ohio Supplement, Fifteenth Census of United States, Composition and Characteristics of Population.

concerns operating. However, one bakery, a link in a large Cleveland chain, dominates the baking field. Because of the retail nature of bakeries in addition to their manufactural characteristics, there is a marked tendency for these establishments to concentrate in the commercial-retail section along Broadway and in the other retail sections. However, the largest baking concern in the city occupying a plant covering almost one-half an acre has a manufactural location three blocks off Broadway.[16] This location is possible because the company operating a fleet of thirty-six trucks offers a house-to-house delivery service and does the retailing directly from these "bakery wagons." These trucks carrying a full supply of bakery goods traverse daily established routes which include the rural sections and the neighboring urban communities beyond. This scheduled retail service has been sufficiently popular for this company to grow and to expand its manufactural unit. Emphasis on the manufacturing phase of the business is in definite contrast to the other baking establishments in which the emphasis is placed on the retail phase of the baking business. Their locations are primarily in the commercial core where better retail advantages are offered.

Other Light Industrial Plants—Standing on the lake front are three average city blocks west of the mouth of Black River and two large plants, the carbo-electric generating station and ice plant.[17] These two plants with their coal storage yards occupy private properties in juxtaposition and together occupy approximately eleven acres of urban land. Their position on the lake front and with properties extending into the lake enable them to pump from the lake the tremendous quantities of clear water needed for condensing purposes. The electric generating plant alone pumps between 30 and 40 billions of gallons of water annually or approximately twenty times the amount used for domestic purposes in Lorain.[18]

Coal for these plants is switched over a short spur line of the Baltimore and Ohio Railroad, a switch extension off of the

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[16]The exact location of this plant is at the corner of 22nd Street and Oakdale Avenue.

[17]The rather questionable nature of classifying these plants in the light industrial group is recognized. Perhaps a separate classification into public services would be more inclusive. But in the interests of economy in space and time and more especially to shorten the list of industrial classes, the manufactural character of these urban industries is here recognized as dominant.

[18]Industrial Survey, *Lorain Journal* gives 43 billions (issue June 6, 1929). In an interview, Engineer in charge gave 40 billions (1931).

main road to the ore docks. Since 140 to 150 cars of coal are consumed and it is necessary to keep a reserve supply, much of the urban land within property lines is used for the storage of coal. Other plant equipment which, in the case of the generating concern, is large, is also stored on company property.

This Edgewater plant is an important generating unit of the Ohio Public Service Company which operates a superpower system serving a large territory in northern Ohio. (Fig. 12). The favorable location of this generating unit with respect to ample supplies of good water and the relative ease in which coal may be obtained have influenced its enlargement until its present production is approximately 60% in excess of the local needs for electric energy. Lorain consumed in 1931 over 47 million kilowatt hours of electric energy which was slightly more than one-third of the amount generated.

The consumption of ice in Lorain and a limited territory outside is sufficient to support a manufacturing plant with a daily capacity of 100 tons. Because the consumption in summer is often twice the capacity of the local plant a large storage plant with a capacity of 3,000 tons is operated in connection. During the months when consumption is below the plant capacity, the surplus ice is stored until a time when consumption is in excess of the manufacturing capacity of the plant. This plant is sufficiently large to keep 16 trucks and thirty to forty men employed, more being employed during the summer when there is the greatest consumption.

C. TRANSPORTATIONAL UTILIZATION

1. *Commercial Relations of Lorain with the Upper Lakes Region*

Lake Transportation and Commerce—Lorain's open door on the navigable waters of Lake Erie has for over one hundred years kept the town in touch with the outside world. Before the railroads came the town's commercial connections were eastward; after the railroads were built, the town profited by the connections with the territory to the north and west. The city landscape of Lorain has always borne the cultural expressions of these connections.

In the modern landscape of Lorain there are not only the cultural forms that express the regional connections, but the magnification of the forms attest the degree of economic

specialization now existent. The modern ore docks on which there are seven unloaders with a total seasonal capacity of approximately seven million tons of ore; the coal-loading machinery with a capacity of more than three million tons annually; the modern steel plant capable of consuming two millions tons of iron ore; and all the necessary harbor facilities, tugs, supply boats, a coal barge for bunker coal, ship repair facilities, etc.; all suggest the regional limitations placed upon the city by specialization.

Modern Lorain has developed as a consequence of the stimulation through trade attracted to the harbor. This modern harbor of Lorain consists of an outer harbor of 60 acres set off by breakwaters and an inner harbor made by extending the river between projecting piers attached to the mainland. This harbor in its modern aspects is largely the result of one hundred years of steady improvement. The continued use of the river mouth encouraged the continued governmental and local expenditures for its improvement. There have been periods (individual instances of which have already been cited) when the main programs of improvement were neglected, but over long periods these projects have gone forward toward completion. The existing project adopted in 1898 provided for the construction of an outer harbor protected by artificial breakwaters and dredged to a depth of 20 feet, is now practically completed. Now only two harbors on Lake Erie are deeper and one as deep as that of Lorain.[20] The completion of the sixty-acre outer harbor and an inner harbor of similar size makes a total of approximately 120 acres in navigable water surface in Lorain harbor. (Fig. 13).

Harbor scenes during the year present two marked contrasts. In the winter the inner harbor is literally filled with long ore and limestone boats lying idle because ice in the river channels prevents their passage into the upper lakes. But the opening of the navigating season is preceded by considerable port activity. Ships in winter quarters are thoroughly cleaned, painted, inspected, boiler and machinery repairs are made, and the port teems with seamen seeking employment. Though there is some shipping on Lake Erie as soon as the ice clears Lake Erie ports, the active navigating season is officially opened when the ice has cleared the channels of the

[20]Transportation on the Great Lakes, op. cit , Chart opposite p. 11

TABLE IV

Year	No. of Ships		Imports					
	Arrival	Departure	Ore	Limestone	Sand	Lumber, Misc.	Fish	% of Ore
1884	232	319	...	...	...	...	...	...
1885	188	211	...	...	...	...	...	...
1886	259	286	...	...	...	...	...	...
1887	301	342	...	...	...	...	...	...
1888	281	365	...	...	...	...	...	...
1889	...	...	...	...	...	...	...	...
1890	383	431	...	...	...	...	...	...
1891	288	305	270,240	46	...	17,917	...	91
1892	285	314	187,000	...	...	9,000	...	95
1893	220	293	171,562	2,134	...	7,135	...	95
1894	481	411	170,278	1,336	...	14,566	...	93
1895	518	508	239,924	14,224	...	23,315	...	86
1896	532	263	215,160	...	...	16,138	1,143	93
1897	725	740	394,511	13,440	...	27,406	...	91
1898	469	451	627,054	10,800	...	80,212	...	85
1899	638	645	1,068,913	36,186	...	39,246	110	96
1900	489	485	1,103,962	450	...	...	...	93
1901	357	403	808,409	250	...	...	...	91
1902	526	515	1,605,421	32,700	19,500	16,299	2,244	96
1903	571	578	1,103,468	26,325	23,000	37,080	500	93
1904	530	567	1,126,514	34,149	114,950	19,031	400	87
1904	792	735	2,016,573	39,948	2,500	19,318	800	99+
1906	854	726	2,417,109	52,268	...	16,927	30,836	96
1907	903	835	2,921,660	57,003	...	9,223	64,089	97
1908	746	730	2,286,356	929	3,842	7,205	2,344	100—
1909	804	764	3,124,656	...	8,491	8,910	2,036	99
1910	1111	1119	2,835,591	...	...	9,912	6,715	90
1911	1303	1300	3,305,357	...	6,990	4,203	250	99
1912	...	...	...	...	...	...	...	...
1913	...	...	...	...	...	...	...	...
1914	973	974	1,872,567	50,856	...	584	2,024	97
1915	1149	1158	3,940,195	31,784	...	797	1,302	99+
1916	2619		5,167,825	57,959	52,215	771	971	98
1917	3287		4,291,044	157,194	55,084	1,128	790	95
1918	4091		3,913,694	103,328	43,165	...	615	97
1919	2899		3,784,952	275,499	6,397	...	285	93
1920	3676		4,508,600	457,073	34,710		680	90
1921	1725		2,002,756	273,791	29,738	...	345	87
1922	2039		3,113,741	435,222	38,310	...	406	87
1923	2240		3,917,653	497,185	15,509	...	508	89
1924	777	770	3,430,828	413,824	17,392	...	410	89
1925	1316	1319	4,610,168	539,558	108,200	...	584	88
1926	1516	1518	4,165,723	556,824	84,100	...	609	87
1927	1528	1526	3,942,412	564,565	161,076	...	719	86
1928	1506	1512	3,822,497	593,783	208,475	5,125	729	83
1929	1414	1417	4,232,579	545,352	235,310	...	564	88
1930	1171	1172	2,835,950	549,267	180,394	1,529	560	79
1931	460	453	2,031,184	226,301	73,415	2,812	773	87

TABLE IV (*Continued*)

Year	Exports				Aggregate Tonnage of Cargo		
	Coal	Billets Rails, Skelp	Misc.	% of Coal	Imports	Exports	Total
1884	...	...	...		50,889	78,847	129,736
1885	...	...	...		43,379	66,525	109,904
1886	...	...	...		84,593	89,498	173,091
1887	...	...	...	...	94,796	130,662	225,458
1888	...	...	...	...	158,481	185,219	343,700
1889	...	...	...	...	...	...	...
1890	...	...	...	...	166,093	185,148	351,241
1891	450,513	...	31	100	288,203	450,544	738,747
1892	35,200	...	...	100	196,234	35,200	231,434
1893	550,194	95,433*	...	85	180,976	645,527	826,503
1894	347,835	...	...	100	186,180	347,835	534,015
1895	281,241	3,164	158	99	277,463	284,582	564.055
1896	332,167	511	...	100	232,439	332,780	565,219
1897	195,000	9,744	...	100—	435,357	207.244	642,581
1898	319,072	...	1,315	97	737,881	329,134	1,067,015
1899	278,102	600	...	97	1,114,345	278,812	1,423,157
1900	402,662	1,055	...	100—	1,124,641	422,068	1,546,700
1901	275,707	...	1,233	96	824,591	276,940	1,101,531
1902	861,739	7,677	3,906	100	1,676,164	873,332	2,549,496
1903	1,148,015	27,800	2,294	98	1,190,373	1,178,109	2,368,482
1904	1,083,719	14,475	...	97	1,295,044	1,098,194	2,293,238
1905	1,180,516	...	18	99	2,084,952	1,180,534	3,265,486
1906	1,807,098	34	1,419	100—	2,517,140	1,808,551	4,325,691
1907	2,166,273	...	473	100—	3,051,974	2,178,446	5,230,420
1908	2,098,674	...	...	100	2,300,676	2,098,674	4,399,350
1909	2,075,911	...	413	100	3,144,093	2,076,324	5,220,427
1910	2,818,715	...	3,134	100—	3,192,489	2,821,849	6,014,338
1911	...	...	...	100—	3,316,800	3,137,467	6,454,267
1912	3,133,672	3,710	85	100—	...	...	7,400,591
1913	...	...	...	...	...	...	8,609,897
1914	2,579,834	577	633	100—	1,926,031	2,581,044	4,507,075
1915	3,036,339	...	...	100	3,974,078	3,036,339	7,010,460
1916	3,668,105	...	...	100	5,279,714	3,668,105	8,947,846
1917	3,023,841	...	...	100	4,505,240	3,023,841	7,529,081
1918	3,525,884	...	...	100	4,060,802	3,525,884	7,686,686
1919	2,750,599	...	...	100	4,067,130	2,750,599	6,817,729
1920	3,471,804	46,449	...	99	5,501,063	3,518,253	8,519,316
1921	2,633,304	1,948	...	100—	2,306,630	2,635,252	4,941,882
1922	1,887,277	23,700	...	99	3,587,679	1,910,977	5,498,656
1923	3,843,866	4,488	...	100	4,430,855	3,848,354	8,279,209
1924	2,247,992	34,446	...	99	3,862,454	2,282,432	6,144,892
1925	1,546,515	34,705	...	98	5,258,510	1,581,220	6,839,730
1926	2,067,655	35,946	...	98	4,806,647	2,103,601	6,910,257
1927	2,704,130	51,830	...	98	4,688,053	2,755,960	7,444,013
1928	2,097,780	64,017	...	97	4,630,609	2,162,697	6,793,306
1929	2,264,670	63,414	1,792	97	4,777,931	2,328,084	7,341,889
1930	1,989,916	31,035	7,407	97	3,585,378	2,028,358	5,613,734
1931	1,450,228	...	18,075	99	2,334,485	1,468,303	3,802,788

upper lakes and the marine insurance rates are declared in effect. This usually occurs around the first of May depending upon the severity of the winter in the region of the Upper Lakes, particularly in St. Mary's River. The season of navigation closes as abruptly. When there is danger to cargoes from ice forming in the channels and the marine insurance is no longer in effect, the season is declared closed. The date of closing varies between the first and fifteenth of December.

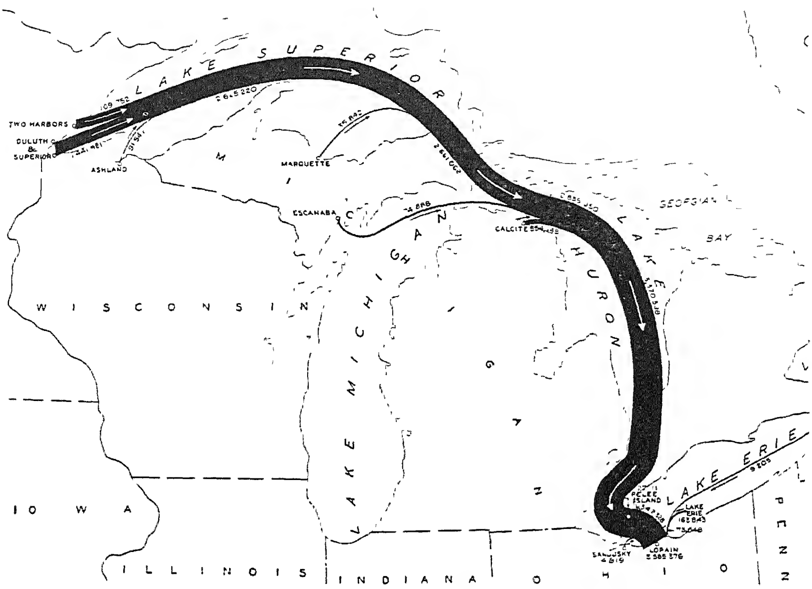
In normal times there is a considerable rush and anxiety to get out of port and under way as soon as the season opens officially. The two tug boats used in Lorain Harbor tow the massive 600 foot ore carriers down the crooked river to the harbor entrances and the local navigating season is open. From the beginning of the season, actually initiated by the departure of the first large carrier, there is a prodigious stream of boats arriving and departing from the harbor throughout the season. In recent years, there have been between 2,300 and 3,000 arrivals and departures in a single navigating season of approximately seven months in length.

Further emphasis of the degree of specialization which grips Lorain is best shown by an analysis of the harbor use. The total average annual tonnage of water-borne freight into Lorain for the years 1921–30 amounted to 6,056,558 short tons of which 65% represented receipts and 35% shipments (Table IV).[21] Iron ore for use in the local steel plant and for transshipment to the interior averaged 3,314,400 tons annually, or 87.9% of the total imports of the city.[22] And when an average annual tonnage of 443,385 of limestone, or 11.8% of the total receipts, is added, making the total 99.7% of receipts composed of bulky freight, the true picture is presented. This leaves only .3% for all other import freight which includes: sand, fish, steel and spiegeleisen. While iron ore dominates the local import tonnage, Lorain ranks only fifth among the lower lake cities in this trade. Cleveland, Conneaut, Ashtabula and Buffalo all import greater amounts of iron ore than Lorain.

Although Lorain has connections by water with all the iron-ore-exporting cities on the Great Lakes, 85% of the total

[21]The ports of Sandusky, Huron, and Lorain, Ohio, Lake Series No. 8, Superintendent of Documents. p. 139. 1932.

[22]The words imports and exports as here used mean. "to carry in" and "to carry out," rather than the usual connotation limiting the words to international trade. The words as here used include both internal and foreign trade so far as Lorain is concerned.



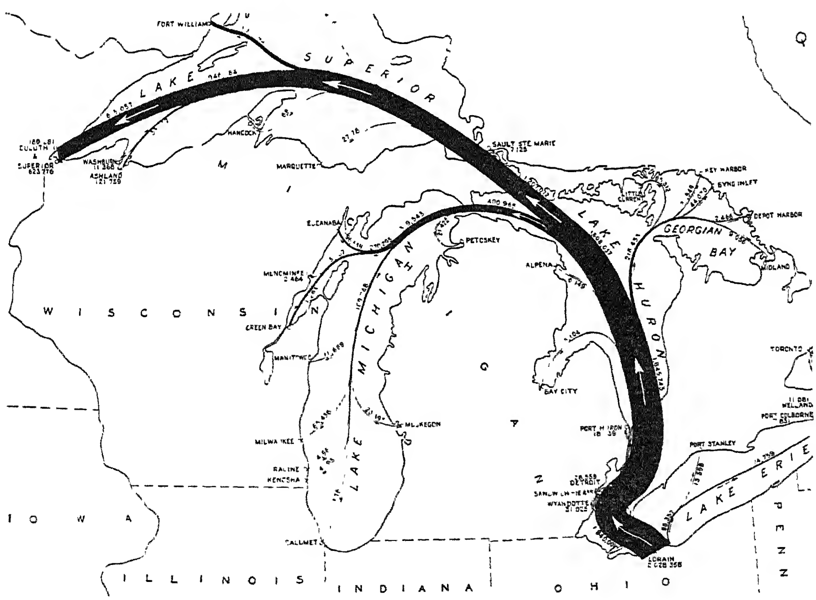


FIG. 14 (upper). Origin of lake receipts at Lorain, Ohio, during 1930, expressed in short tons (Corps of Engineers, U. S Army).
FIG. 15 (lower). Destination of lake shipments from Lorain, Ohio, during 1930. (Corps of Engineers, U. S. Army).

ore tonnage received at Lorain comes from the cities at the head of navigation on Lake Superior, namely, Duluth, Superior, and Two Harbors. (Fig. 14). Ashland, Marquette, and Escanaba contribute the remaining 15%. So cheaply and efficiently is this iron ore transported over the thousand-mile lake route, that, from the standpoint of rates, Lorain is closer to Duluth by water than to the furnaces of the interior by rail. The rail hauls vary between 100 and 200 miles. Through this water connection with the iron ore fields, Lorain has been enabled to develop industrially and commercially.

TABLE V

IRON ORE SHIPMENTS

By Water to Lorain		By Rail from Lorain	
From	Rate Gross Ton	To	Rate Gross Ton
Duluth	.70	Dover, Ohio	88
Superior	.70	Wheeling, W. Va	1 15
Two Harbors	.70	Scottsdale, Pa	1 30
Escanaba	.82	New Castle, Pa	88
Marquette	.63	Pittsburgh, Pa.	1 15
		Youngstown, Ohio	82
		Steubenville, Ohio.	.99
		Sharon, Pa	.82

The export trade of Lorain is even more specialized than the receipts. Over 99% of this tonnage is coal consigned to the fringe cities on the upper lakes in both Canada and the United States, and in bunker coal for vessels in and out of Lorain (Table IV). Although the foreign trade in coal is only 7.3% of the total exported and is entirely with Canada, this tonnage is far greater than the imports from foreign countries which amount to less than .1% of the total port tonnage. (Fig. 15).

Among the coal exporting cities of the Lake Erie shore line, Lorain ranks fourth, following Toledo, Sandusky, and Ashtabula. This condition exists in spite of the fact that Lorain is on a more direct route from the Appalachian coal fields to the navigable channel of the Detroit River where all Lake Erie sailing routes converge (Fig. 16). This is because the differences in length of the land hauls, and the consequent difference in rates that would ordinarily occur, are absorbed by

rate adjustments on cargo coal, thus placing coal export cities on a more nearly even basis.

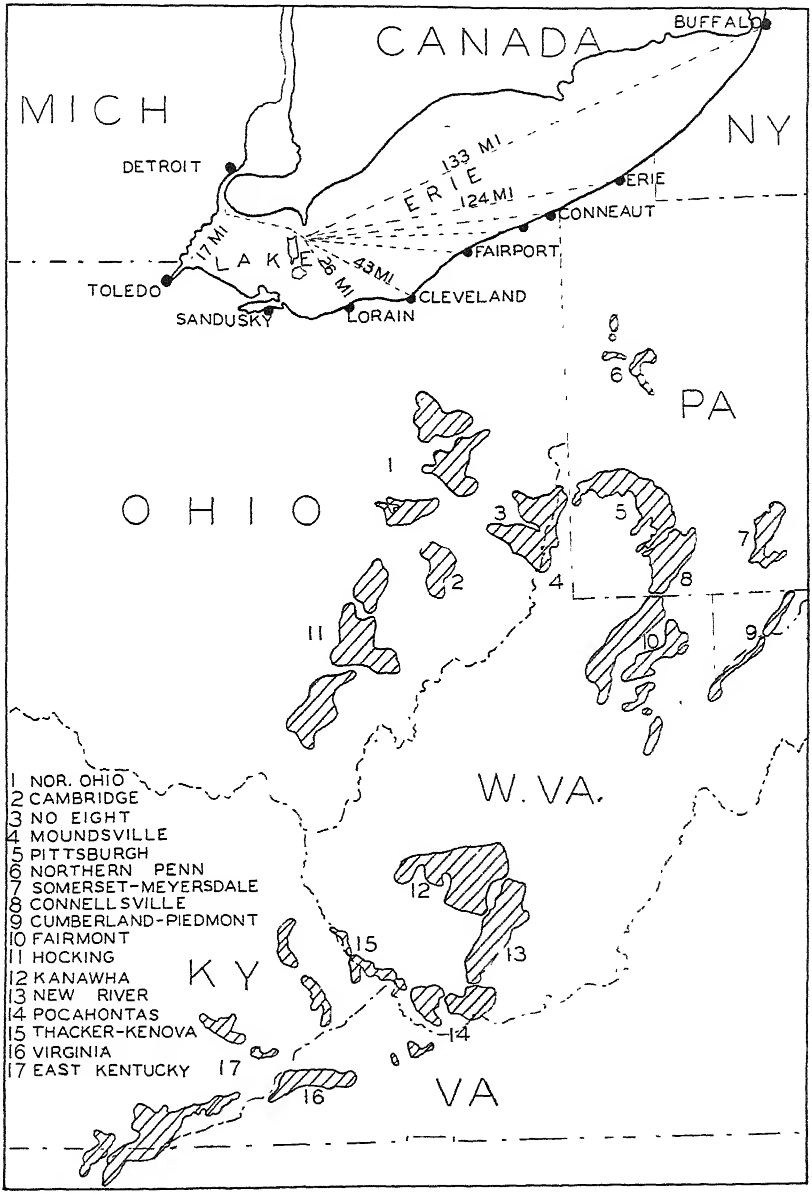


FIG. 16. Location of Lorain in relation to the principal coal fields of the Appalachian Plateau.

Comparisons with other cities to give relative ranks are somewhat misleading, as regards the relative importance of the trade in the local community, because ranks give a regional picture. For example, Lorain ranks fourth as a coal exporter, fifth as an iron-ore importer, and third after Cleveland and Buffalo as an ore consumer. But not until these relative tonnages are placed upon a per capita basis, or on a basis of unit area of urban extent, is the importance of these imports and exports to each city fully realized. On a per capita basis, the consumption of iron ore in Lorain is 41.3 tons, in Cleveland 3.1 tons, and in Buffalo 9.3 tons. In this way the relative importance of the iron and steel industry in each community is pictured.

2. *Hinterland of Modern Lorain*

The Railroad Pattern—Four steam railroads and one electric line help to serve the land transportation needs of modern Lorain. Two roads, the Baltimore and Ohio and the Wheeling and Lake Erie, extend in a southeasterly direction; while two others, the New York Central and the Nickel Plate (New York, Chicago and St. Louis), besides the Lake Shore Electric run in east-west directions from Lorain. Only two of the steam roads, the Baltimore and Ohio and Nickel Plate, offer passenger service out of Lorain. These roads have depots in West Lorain at Eleventh Street where they cross (Fig. 5). No other steam railroads serve West Lorain though they all have connections with South Lorain. The Lake Shore Electric running from Toledo to Cleveland follows the lake shore, passes through Lorain, and gives excellent passenger and freight service east and west. This line, is said to be the longest in the United States under one management and is a link in a very complete system that extends as far south as Louisville.[23]

The railroads of Lorain are characterized, not by their passenger facilities and service, for these are unimportant, but by their facilities for handling and transporting bulky goods. Since all railroads derive most of their revenues from the freight business, they place an emphasis upon a development of this service. And, although South Lorain has connections with four steam railways, no passenger depot or service is offered from there. Only the electric railroad offers

[23]Wright, op. cit., p. 287.

passenger service from South Lorain to neighboring towns and cities. (Fig. 17).

Although the same lines of railroads are essentially the same as during the previous period, there have been marked local changes. All roads have made connections with South Lorain since the establishment of the Johnson Steel Company there in 1894. Moreover, there have been enlargements made in the car storage and switch yards to accomodate increased tonnages both in and out of Lorain. The combined capacities of port facilities for handling and shipping ore is approximately seven millions of tons, or almost twice the average annual tonnage received at Lorain harbor.

Next to residential and industrial, the greatest amount of urban land utilized in Lorain is devoted to transportation (Fig. 5). This condition reflects both the time when urban land was cheap and the modern needs of the carrier roads for large amounts of land at the place where the bulk freight is broken. Most of the urban land devoted to transportational use lies along Black River. Of the total river frontage of 31,350 feet, railroads own 14,330 feet or 46% while industries own 28% and private owners less.[24]

The total tonnage carried on all railroads is one-fourth to one-third greater than the water-borne tonnage. This difference represents the consumption of raw materials by the local industries of Lorain. The business, initiated by the demands of the local manufacturing plants for raw materials of the hinterland is quite separate from the business of transhipping freight. In order to show the character of this dependence as well as the specialization in the regional aspects of each railroad connection, a separate treatment of each road is necessary.

Baltimore and Ohio—Next to the National Tube Company, the Baltimore and Ohio Railroad owns and uses the greatest amount of urban land in Lorain. Upwards of 150 acres, or approximately 3% of the urban land is controlled by title. The land lies along the banks of the navigable Black River to the north of the stream giving a water frontage along company property of approximately one and a half miles. This represents the greatest water frontage along the navigable section of the river owned by any individual or corporation.

This railroad has developed on this property the necessary

[24]Ports of Sandusky, Huron and Lorain, Ohio, op. cit., p. 108.

facilities for exporting coal that originates in its territory and for unloading ore to be transported to the furnaces located in the territory served by the railroad. A coal wharf 790 feet in length and equipped with a Motylor car tipple having a capacity of 25 cars hourly, is located on a bend in the river opposite Fourteenth Street.[25] (Fig. 18). This is the only coal exporting equipment in Lorain. Immediately adjacent to the coal docks, the company's car storage yard with a capacity of 2,500 railroad cars has been constructed.

At the mouth of the river the company has constructed an iron ore dock 710 feet in length and equipped with three electrically operated, 15-ton clam-shell unloaders. An electrically-operated ore bridge of 500 tons hourly capacity is used to transfer the ore to stock storage piles for customer furnaces located inland.[26] In addition there are freight car repair shops and a locomotive roundhouse.

As related in detail elsewhere, the Baltimore and Ohio Railroad connects Lorain with the Appalachian Coal fields, particularly those of southeastern Ohio, southwestern Pennsylvania, eastern Kentucky, and West Virginia. In order further to ascertain the local benefits to industry and contributions to Lorain's development this railroad connection makes, it is necessary to analyze its tonnage. (Fig. 17.)

The iron ore tonnage out of Lorain to the interior furnaces over the B. & O. railroad is for the most part consigned to independent steel companies and amounts to less than 150,000 tons annually, or less than 5% of the total iron ore tonnage received at Lorain. Because most of the ore is for direct shipment the tonnage, when isolated from that of other freight, shows a distinct seasonal allegiance.

Lorain's development into a coal transhipping port has come about through the connection the city has had via the Baltimore and Ohio railroad with the coal fields, particularly those fields that produce steam and domestic fuel coals, those in greatest demand around the fringes of the Great Lakes. Moreover, the Baltimore and Ohio railroad employs between 400 and 500 workmen in the roundhouse, the car shops, on the coal and ore docks, in the offices and in running the trains. This number is about one-half of the total number of railway employees in Lorain.

[25]Ports of Sandusky, Huron and Lorain, Ohio, op. cit., p. 120.
[26]Ibid., p. 119.

The Wheeling and Lake Erie Railroad—The Wheeling and Lake Erie railroad does not enter West Lorain, but approaches the city from the southwest, continues eastward three miles south of the city and enters South Lorain from the east. Connecting South Lorain with the Pittsburgh District, the road parallels for a distance the Baltimore and Ohio already referred

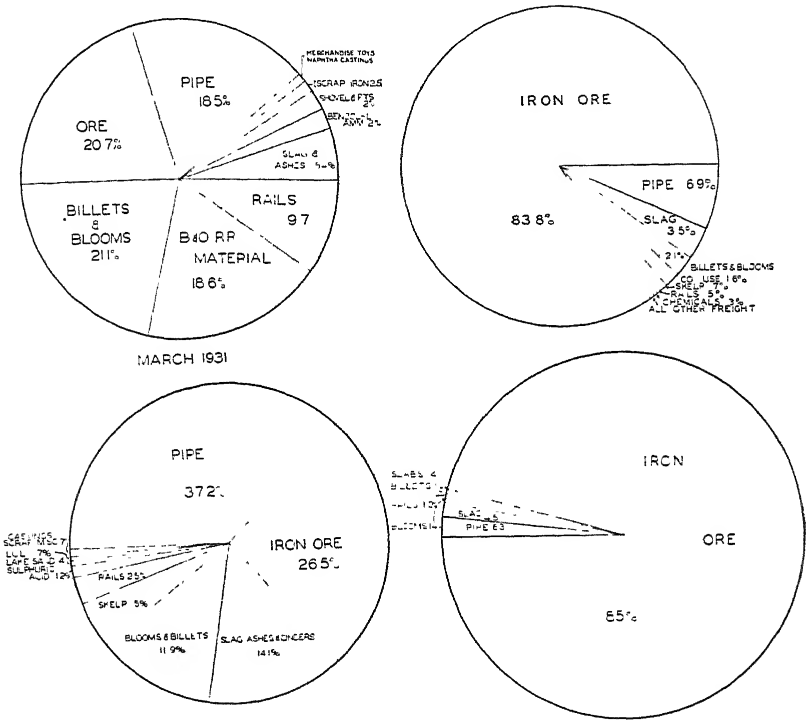


FIG. 17. Commodity analysis of outbound freight over individual railroads. Upper left, B. and O. R. R.; upper right, Nickel Plate R. R.; lower left, New York Central R. R.; lower right, Wheeling and Lake Erie R. R.

to. This road is strictly a freight line, no passenger service is offered and no depot facilities provided. The road connects the National Tube Company's plant with the coal producing western Pennsylvania and iron-ore-consuming Pittsburgh and Steubenville districts.[27]

By taking a circuitous route around the city and entering

[27]Pittsburgh district includes: North Bessemer, Clairton, Donora, Etna, Rankin, McKeesport, Midland, Monessen, South Duquesne, and Woodlawn. The Steubenville District includes Mingo Junction and Weirton.

the National Tube Company's property soon after crossing the corporate limits of the city, this railroad has only a narrow right-of-way with a very limited urban extent. Therefore the amount of urban land used by this railroad is so small in relation to that occupied by other carriers, it may be considered negligible.

That this is a railroad specializing in raw materials is best shown by the tonnage. Coal into Lorain makes up 80–95% of the total inbound tonage (Fig. 19). Practically all of this coal consists of two grades, one from Standard, Penn., and another from Gary, W. Va., used in the coking plant of the National Tube Company. An average of over 98% of the total inbound freight of this railroad represents materials used in the National Tube Company's plant.

The outbound tonnage shows the same degree of specialization. The entire tonnage originates in the National Tube Company's plant and moves to interior iron and steel centers, particularly to the U. S. Steel plants at McKeesport and Denora. The iron ore, constituting 85% of the outbound tonnage represents a portion of that from the ore docks of the National Tube Company. There are not the seasonal fluctuations in this flow of tonnage that characterize the tonnage of the Baltimore and Ohio, because the National Tube Company has the facilities for storing the ore thus permitting it to flow more regularly to interior furnaces through the winter season.

While the total tonnage of this railroad is only about 30% of the total tonnage of the Baltimore and Ohio railroad, the Wheeling and Lake Erie connection is of great importance to local industries of Lorain.

Nickel Plate Railroad—Giving Lorain a fast east-west freight service, the Nickel Plate connects with the large eastern and western urban centers. Toward the west Sandusky, Fort Wayne, Lima, Indianapolis, Chicago, Peoria and St. Louis are urban centers connected by this railroad to Lorain; while toward the east, the connection is with such important cities as Cleveland, Buffalo, Rochester, Syracuse, Troy, and New York. In Lorain a narrow right-of-way averaging 150 feet in width and running in a northeast-southwest direction straight through the city, has been developed with switch tracks, warehouses, and both passenger and freight depot facilities. The crossing of Black River is accomplished over a structural tressel interrupted by a 400-foot swinging bridge that spans

the river (Fig. 5). The bridge is located three-fourths of a mile upstream from the mouth and is on a level with the lake plain surface, about thirty-five feet above the water.

Another Nickel Plate connection is made by means of a spur-line which branches off of the main line two and a half miles east of the city limits. This spur line avoids Black River gorge, runs south, and enters South Lorain from the east.

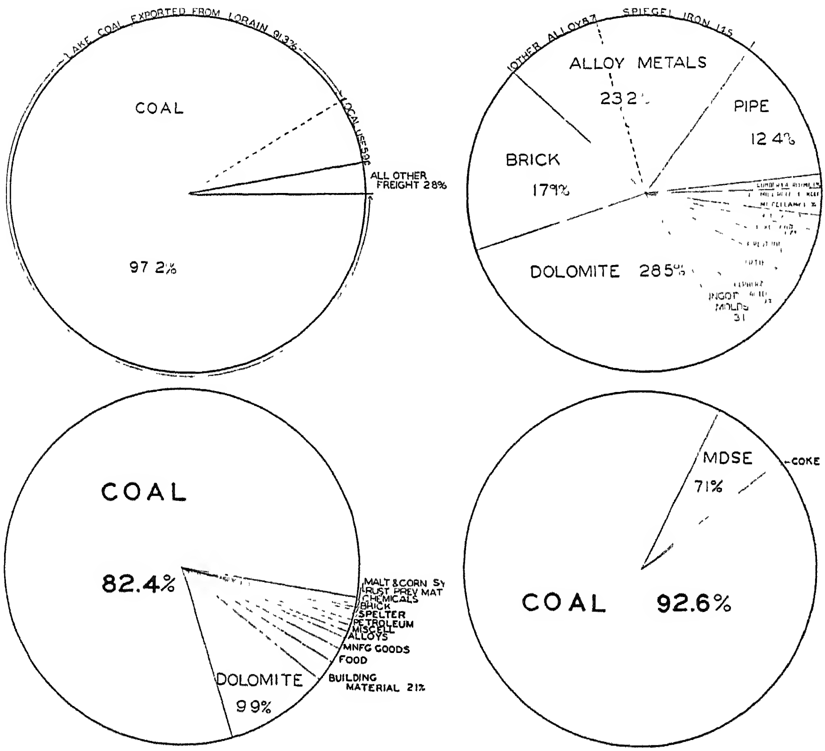


FIG. 19. Commodity analysis of inbound freight over the individual railroads serving Lorain. Upper left, Baltimore and Ohio R. R.; upper right, New York Central R. R.; lower left, Nickel Plate R. R.; lower right, Wheeling and Lake Erie R. R.

These two Nickel Plate connections with Lorain have divided the business in such a way that two railroad offices are maintained. The one in South Lorain is a consolidated freight office handling the South Lorain business for three roads, the Nickel Plate, the Wheeling and Lake Erie and the New York Central; while the Lorain office (on the main line) handles exclusively the business of Lorain.

This road is Lorain's second largest freight carrier with a total tonnage equal to approximately 40% of that carried by the Baltimore and Ohio railroad. Although the downtown office is on the main line of the railroad, only 20–25% of the tonnage is handled through that office and 75–80% in the South Lorain office. Two distinctly different classes of freight are handled at the two different offices. Long trains of raw materials coming in and of heavy bulky materials going out is characteristic of the South Lorain, while the Lorain freight is characterized by package freight, and individual carload shipments and receipts. The significance of this road to the industries of Lorain is shown by the commodity distribution of the South Lorain division of the road. The two most important are coal, principally for the coke plant, and dolomite for use in the blast furnace. This coal originates in the Pittsburgh district (Muse, Pa., and Mifflin Junction, Pa.) and from Gary, West Virginia, but is fed northward to the Nickel Plate by other railroads that serve the coal fields. Raw materials for industries being in constant demand there is a regular flow of traffic in the inbound tonnage.

The outgoing tonnage of the Nickel Plate is dominated by the transhipments of iron ore from the National Tube docks. The volume of freight in the summer months over this road is as much as fifteen times what it is during the winter months. Often the railroad facilities are taxed to the limit for a short season, then there is a quiescent period when most of the ore is moved to furnaces in the Mahoning Valley. When conditions like this prevail men are placed on a waiting list and employed from day to day. Pipe from the National Tube Works is the next most important article shipped. This pipe moves in two directions over the Nickel Plate—southwest to oil fields and east to export points.

Although coal also dominates the freight business of the Lorain office of the Nickel Plate, food supplies make a sizeable showing. This railroad connecting as it does with eastern and western cities is the general household supply road for the city of Lorain. Monthly consignments of eighteen to twenty carloads of meat from Chicago, ten carloads of wheat flour from Kansas and Minnesota, manufacturers from New York, malt and corn sugar from Argo, Illinois, are important household supplies carried and are examples which show the significance of this railroad connection. This freight is character-

ized by an almost incredible number of articles and provisions needed in the homes of Lorain. The coal that enters so prominently into the tonnage is the steam coal used in the carbo-electric generating plant and domestic coal to local coal dealers of Lorain. No export coal shipments are brought to Lorain over any railroad except the Baltimore and Ohio.

New York Central—The main line of the New York Central railroad from Chicago to New York does not touch Lorain but runs through Elyria eight miles south. However, a spur line extends from the east edge of Elyria northward parallel to the course of the Black River to connect with the other three railroads that enter South Lorain from the east. This gives a rather indirect connection with the main line but is important because the road makes available a certain territory not served by other railroads of Lorain. Only freight service is offered over this railroad, and the business is handled at the South Lorain consolidated railroad office.

By reason of the indirectness of its connections with Lorain and because this railroad serves no particular section of the country that is exclusive in the production of raw materials, the railroad tonnage of the New York Central is the least of any line serving Lorain. That it is not a transporter of raw materials for local industries but rather a service railroad transporting finished products is shown by the excess of outbound freight over inbound tonnage. This excess reaches a maximum during the summer when iron ore for transhipment to "Valley" furnaces is added to the finished products of the National Tube Company. And for some months during the summer iron ore tonnage surpasses the tonnage of steel pipe, but manufactured steel pipe moving to world markets normally dominates the outbound tonnage. Shipments of pipe are characteristically large scale. Long trainloads move out in response to the orders from oil and pipe-line companies. Orders for pipe sufficient to construct a pipe line five miles to one hundred miles in length are not uncommon. Of all the outbound freight over this road, manufactures from local industries make up more than 72% of the total and the industries are responsible through organization for 98% of the total. (Fig. 17).

The inbound freight over the New York Central railroad is shown to be dominantly raw materials of a specialized nature. Refractory brick, alloy metals and dolomite make

up 68.8% of the total tonnage. Pipe made in other plants and which constitutes 12% of the tonnage is transported to the Lorain mills for further processing or to help fill very large shipments out of Lorain.

By the more even distribution of commodity tonnage over this road, hence a less tendency toward seasonal fluctuations, the number of employees affected by the temporary nature of these jobs is less than for other railroads. However, the employment of men is done through the consolidated office in South Lorain, the monthly expense of which is borne by the participating railroads in proportion to the monthly tonnage handled. This cooperative practice of the railroads militates against the seasonal fluctuations of railroad employment.

Highways—Lorain has a network of concrete and macadam highways consisting of one major through highway, four secondary highways, and several county feeder roads. The highway of primary importance in truck and car traffic is the "Lake Road," or Erie Avenue through Lorain, which connects with Cleveland on the east and Vermillion, Sandusky and Toledo towards the west. This road, known as Federal highway No. 2, is of the boulevard type through Lorain, being sixty-six feet wide from curb to curb and well improved. The traffic over this trunk highway is heavy and of three types: tourist traffic attracted to the route because of its scenic location along the lake shore; the heavy truck traffic between the cities, particularly Cleveland and Toledo; and the local automobile traffic that is made heavy by the many north-south county feeder highways. No other highway in Lorain approaches this one in the volume of traffic handled. Fleets of heavy trucks bearing supplies from Cleveland to the local merchants, and long trailer trucks hauling automobiles, automobile bodies and parts between Cleveland and Detroit, or Toledo, characterize the heavy traffic on this important highway.

The Lorain system of seconday highways consists of three highways which enter Lorain from the south, and one highway which enters South Lorain from the east. None of these roads is continuous through Lorain but function as important cross highways between the "Lake Road" and the "Ridge Roads," which parallel roughly the former. In its functions, the South Lorain highway is the same as the north-south system for West Lorain. Only one, Leavitt, at the west edge of Lorain, has been designated as the beginning of highway No. 58 (Ohio

state highway) and carries a limited traffic in a southerly direction. For Lorain this secondary system performs two important functions: (1) it connects with the county's system of local roads, thus making connections with the rural labor supply for Lorain industries; and (2) it concentrates cross country travel by the converging pattern, which terminates at Lorain. The abrupt ending of these roads at the Lake Shore highway brings some business to the city which would be lost if these roads were through highways. Although these highways are important locally, they are narrower, less direct, and have more of a perfunctory nature than the Lake or Ridge roads. In every instance, these roads merge with the important through traffic streets in the local pattern. But these have been fully described elsewhere.

D. COMMERCIAL UTILIZATION OF LORAIN

1. *Segmental Character of the Commercial-retail Section*

General Characteristics—The retail-commercial development really consists of one long commercial core along Broadway in West Lorain, one commercial-retail nucleus in East Lorain, and four distinct nuclei in South Lorain. And while there is a tendency for these quite isolated nuclei to be joined to the main commercial-retail core of the city by means of street railways, through uninterrupted street traffic, etc., they are quite separated from each other by long sections of undeveloped urban land. Except in the case of the Pearl Street commercial-retail section in South Lorain, this segmentation is due to physical separation rather than independence of function.

Of these major concentrations two-retail-commercial centers, or nodes developed early. One node occurs on Broadway near the intersection of Erie Avenue and Broadway, and the other at the intersection of Pearl Avenue and Twenty-eighth Street, the location of the general offices of the National Tube Company. (Fig. 21). These two nodes, located three miles apart and each maintaining a considerable degree of individuality, have been persistent centers of later development.

The total area devoted to commercial-retail development is large.[28] An abundance of land has been available throughout

[28]The commercial-retail section is made somewhat larger by the inclusion of certain business types that sell their services as well as those that are purely retail business types. Such are: cleaning establishments, gasoline filling stations, garages where the retail function predominates, printing offices, as well as the purely retail establishments have been classified as commercial-retail. (Fig. 5).

all periods of Lorain's expansion and as a consequence the characteristic development has been to occupy much surface rather than to develop vertically. The commercial-retail pattern, therefore, presents a sprawled aspect instead of a much concentrated nuclear form. Tall buildings are the exception and not the rule. There is but one five-story building and five four-story structures, three in West Lorain and two in South Lorain.

There are in Lorain approximately 610 business establishments here classified as commercial-retail.[29] Of this number 25% are grocery stores, 7% are meat markets, 14% are clothing, dry goods and department stores, 5% hardware stores and 1% drug stores. The preponderance of these provisional stores is evidence of the dominantly laboring characteristics of the population, and harmonized with the industrial-commercial functions of the city.

Because of the secondary and concentrated nature of retail and commercial establishments, the true proportional importance of these establishments in the life of the city cannot be measured by the surface utilization alone. Where an occupational measure is applied, it shows that the commercial-retail activities of Lorain actually support over 3,000 wage earners and is next to the basic iron and steel industries of Lorain. Thus the commercial-retail section is not only important from a functional standpoint, but also supports a large aggregate[30] number of people who in turn constitute a large portion of the city's population and are in part responsible for its institutions. The provisioning establishments which are so characteristic of Lorain employ 55% of the wage earners in the group of secondary establishments.

In order better to present the local picture of the large commercial-retail development of Lorain it is necessary to refer separately to each of the commercial nuclei that make up the whole picture.

Broadway Core—The principal commercial-retail section of Lorain starts at Erie Avenue and stretches southward along both sides of Broadway for a distance of two miles (Fig. 5). The west side of the street being much more intensively utilized than the east side where there exist some conflicting

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[29]"Lorain, the City," publication of the Chamber of Commerce, p. 16, 1928.

[30]Fifteenth Census of United States, Supplement on Character and Composition of the Population, Table 25.

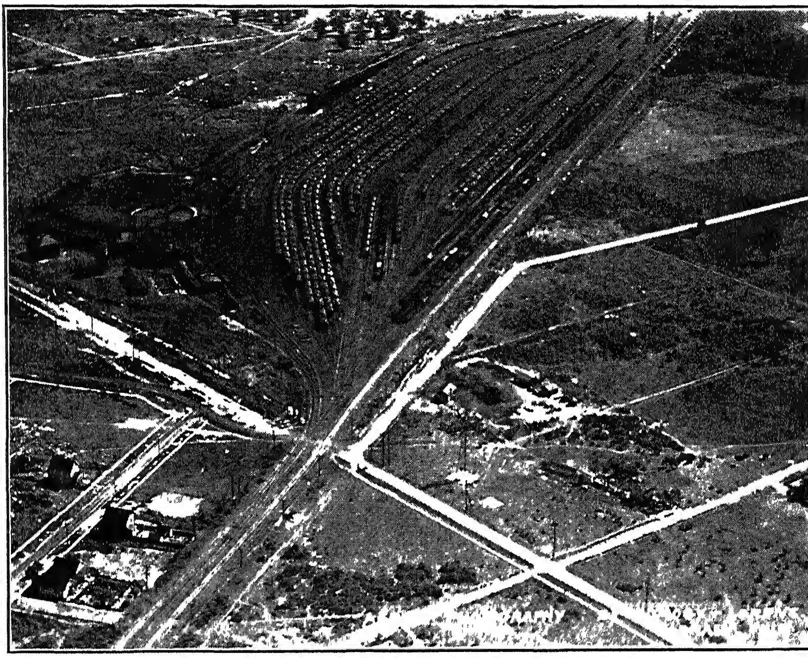
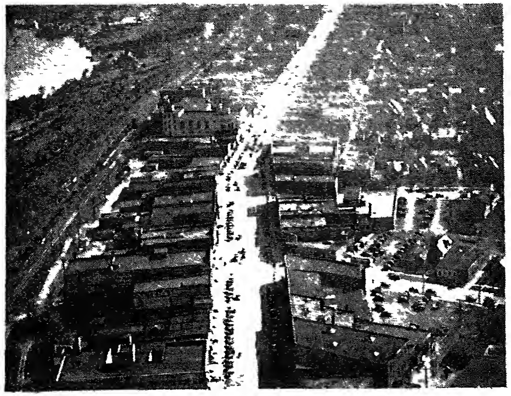


FIG. 18. Aeroplane view of Baltimore and Ohio Shops and Car Storage Yards adjoining the corporate limits of Lorain.



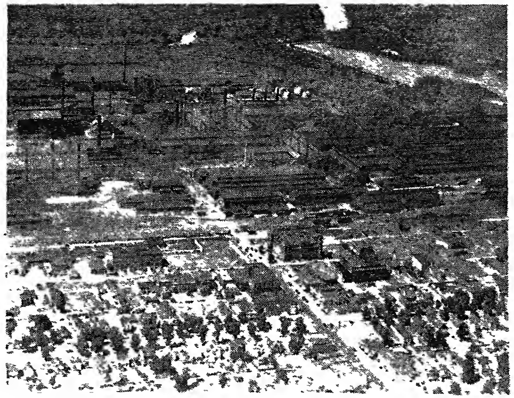


FIG. 20 (upper left). Broadway looking south, a portion of the long commercial retail core of Lorain.

FIG. 21 (upper right). Principal commercial retail nucleus of South Lorain. Main offices and a portion of the National Tube Company's plant are also shown.

FIG. 22 (lower). Residential section of West Lorain between Broadway and the plant of the National Stove Co.

Photos by Somogy-Lorenz, Lorain

urban associations. Commercial-retail development has possessed generally about one-half the block along the side streets at right angles to Broadway so that the zone of commercial encroachment upon the residential area is a rather limited one. In no other single instance throughout the entire length of Broadway, except along Erie Avenue, has the development fully occupied the first block along the side streets. While the Broadway side of the block is commercialized, the other three sides away from Broadway are mostly residential. (Fig. 20).

On the east side of Broadway no opportunity for side-street development occurs. There exists only sufficient space between Broadway and the Baltimore and Ohio railroad tracks for one fourth of a block, which faces Broadway. Thus, all the east-west streets that cross Broadway terminate at the railroad tracks less than half a block east of Broadway. Therefore, there is no space for any side street commercial development on the east side of the core. This and the frequent vacant lots on the east side of the street give an unbalanced appearance to Broadway.

Although this main commercial-retail core gives the appearance of being continuous, there exists a local segmentation due apparently to an unevenness of opportunities for retail trade along this long street. Beginning on Broadway at Erie Avenue and continuing south, there is intensive utilization and an even skyline with closed structures until the railroad tracks are approached. Open spaces and less desirable structures then continue for seven or eight blocks. Where Broadway turns more directly south and thus avoids merging with Elyria Avenue, the opportunities for retail trade are increased by the intersection of two busy streets carrying through traffic. There results a more intense commercial utilization of the land and three blocks of closed structures. From this point the commercial-retail intensification again diminishes progressively south until Broadway intersects Twenty-eighth Street, which runs east in front of the National Tube Company's property. Again on this corner there exists a retail nucleus.

The profile of Broadway is a monotonously even succession of low, flat buildings. Only in the first two blocks on the east side of Broadway and the first four blocks on the west side are there enough three-story buildings to break the generally even two-story skyline. Brick and stone structures prevail on the west side of Broadway and are only interspersed with

frame buildings in the open associations that tie together the commercial segments of Broadway. While on the east side brick buildings extend generally only four blocks south from Erie Avenue before giving way to frame structures.

The occupation of Broadway as the commercial core of the city was in part inherited from the former periods when commercial-retail contacts with Black River were imperative, hence the first street that paralleled its course was the one occupied. This is shown by the intensive development in former periods of the block on Broadway west of Erie Avenue. Here the closeness of the river made business property much in demand. This condition obtained as long as Black River was used for general shipping activities. At present the vacant lots, decadent frame buildings, and the recognized undesirability of North Broadway (north of Erie Avenue) as a location for business houses show the change to be a relatively recent one. However, modern development has been south on Broadway and has resulted in an extremely long, drawn out, interrupted commercial-retail core. This development shows an allegiance to two important market forces, South Lorain where there live and work approximately one third of the population of Lorain, and West Lorain by inheritance the center of the city.

While there are in Lorain approximately six hundred business establishments that run the whole gamut of business types, the Broadway core possesses certain characteristics that harmonize with the city's industrial character. The preponderance of supply stores, such as grocery stores, meat markets, dry goods and notions, etc., show that the merchants cater to a laboring population. Many of the stores, especially the small provisioning establishments, are run by foreigners and cater to the special demands of the foreign element in Lorain.

Away from Broadway there is a surprisingly large number of retail establishments, most of which are grocery stores. The average number is three in every city block in the older sections of West Lorain. Practically all are small combination retail-residential establishments. These combination stores are especially numerous in the foreign sections where the store is run to supplement the family income. The man of the family usually works in the steel plant, and the store is run by members of the family who live either upstairs or in the back portion of the same building. While these combination

retail-residential establishments are more numerous and more uniformly typical of the foreign districts of the city, they also appear, usually modified, in other parts of the city particularly along the streets leading out of the city.

Along the east side of Broadway there exists some striking business associations not wholly commercial-retail. Along the narrow blocks may be found small factories, retail stores, coal yards, lumber yards, and old residences. Such uses reflect the relative abundance of commercial land and the rather extensive ways in which it is utilized. The coal and lumber yards extend to the Baltimore and Ohio railroad tracks where they receive their supplies. The retailing is done from offices which front on Broadway. These are relics of a former day which have remained because of the adequacy of commercial frontage on Broadway.

South Lorain Nuclei—The commercial-retail development in South Lorain is in contrast to the long Broadway core of West Lorain. Instead of being one long, more-or-less unified, commercial core, there are five business nuclei that exist quite apart from each other. All begin at Twenty-eighth Street (the street in front of the steel plant) and have their extensions along the north-south streets of South Lorain. Thus each nuclear development has the form of a T. The most important commercial-retail nucleus is at the intersection of Pearl Avenue and Twenty-eighth Street where the General office of the National Tube Company is located. Others are located at the Twenty-eighth street intersections of Vine Avenue, Globe Avenue, Seneca Avenue, and Grove Avenue.

The whole nuclear development shows considerable independence from the main core. Here are located separate real estate offices, the oldest bank in Lorain, the main offices of the National Tube Company, and independent railroad office, and many other smaller types of business that have little connection with the commercial core of Lorain proper. Yet all are enough unified to show that although they have developed individually as a consequence of the local market, they have collectively been the commercial-retail node that has tended to draw out the commercial-retail core on Broadway. The attractive market in South Lorain and the street electric railway connecting the Broadway core with the South Lorain nuclei have enchanced the desirability of the intervening urban land along Broadway. Good retailing opportunities occur at

points between the South Lorain Market and the commercial-retail node at Broadway and Erie Avenue.

Not only do the South Lorain nuclei show that they have developed as a consequence of the local market afforded by thousands of employees of the National Tube Company, but they are quite independent of each other. Each South Lorian nucleus is located in front of an important gate to the National Tube Company's plant. At each entrance hundreds of employees, or even thousands in normal times, enter and depart daily. In order best to serve the employees the commercial-retail establishments have selected sites along those streets most frequented by the workmen as they go and return daily from their homes to work in the plant. This local market condition has caused the elongation of the commercial-retail nuclei in the direction of the residential South Lorain rather than an intensive utilization of the Twenty-eighth street frontage. Moreover, the marked localization of business types in these nuclei is related to the same condition. Along the side streets are for the most part the home provisioning stores such as grocery, small hardware, drug and clothing stores; while along the Twenty-eighth Street frontage are the more general business types; pool halls, restaurants, rooming-houses, banks, garages, etc.

Each nucleus is an intensive cluster of brick buildings in close association, near the street intersection, but gives way quickly to open associations of frame and brick structures away from the street intersection. On Twenty-eighth Street less than half of the block is occupied by buildings, the remainder being left vacant.

Every retail-commercial cluster presents an abundance of evidence of an ethnic influence.[31] Since racial groups attempt so far as possible, to collect in certain residential sections and to work in the same plant units, these business establishments in certain nuclei show a racial affinity.

The combination retail-residential buildings reach their maximum frequency in South Lorain (Fig. 5). More than one-half of the buildings housing retail establishments also

[31]The following named business establishments selected at random exemplify the cosmopolitan atmosphere of those commercial-retail nuclei: Magyar Konyha, restaurant; El Morelos, pool room; Samaha's restaurant; Hungarian-American Barber Shop; Zboray's Haberdashery; A. Donerkeil, grocery; Repertorio-National-Mexicano; Andrew Mitre, notary public; Valeff, real estate; Palagyi Shoe Shop; J. J. Ockajik, grocery, etc.

provide the living quarters for the proprietor's family. As in West Lorain, these establishments usually attract a certain racial clientele and are run by members of the family while the man is employed in the steel plant. Occasionally the establishment has been sufficiently successful for the owner to devote his entire time to the business. The presence of so many of these supplementary business houses gives a peculiar foreign character to the commercial-retail sections in South Lorain.

East Lorain Nucleus—The commercial-retail section of East Lorain has developed across the river from West Lorain is in reality very closely related to the Broadway core. Except for its physical separation, this section is so small in comparison with the others considered that it hardly warrants separate treatment. Here are located the filling stations, the low, broad buildings housing automobile agencies, as well as several small provisioning-supply stores conveniently located for the people living in East Lorain. The first five blocks eastward from the end of the bridge and fronting on Erie Avenue are recognized by a city zoning ordinance as commercial and these are the only ones where any commercial development occurs. A few provisioning stores, mostly grocery stores, are located along Colorado Avenue and in front of the plant of the American Shipbuilding Company. While the isolation of East Lorain from the main commercial has been the means of some retail-commercial development, contacts are sufficiently easy to discourage any pronounced development. Little retail development occurs on East Erie Avenue because of the through nature of the traffic and ordinance regulations which prevent that form of development.

E. RESIDENTIAL UTILIZATION

1. *Residential Sections and Types of Houses*

Lorain as a Residential City—Modern Lorain is essentially a residential city for its own industrial wage-earners. Though the city has over 44,000 people, of whom 12,000 are employed in the primary industries, there remain approximately 5,000 wage-earners who live in Lorain but who are employed in other industries.[32] There are 8,307 dwellings in Lorain which are

[32]There are in Lorain 17,726 gainful workers. Fifteenth Census of U. S., Ohio Supplement, Occupational Statistics, Table 8.

required to house these people and which utilize approximately 60% of the occupied urban land in the corporate limits.[33]

The modern appearance of Lorain's residential sections results from the recency with which the city has had its maximum growth. Seven-eighths of the population has come to Lorain since 1890 and the residential sections have been extended proportionately. Architectural styles have not changed sufficiently in the last forty years to render any residential section conspicuous because of the age of its buildings. Any old structures that have remained tend to be lost in averages or rendered inconspicuous by the modern structures that surround them. Most of the old residences that occupied the downtown streets have been destroyed to make space for either more modern residences or for commercial purposes. Moreover, most of the residential types have been constructed since building and zoning regulations came into effect which have operated to produce an equality of appearance, value and conditions.

Although there exists some variation in the quality of the residences and of the residential sections, or even with residences within the same locality, there is a remarkable evenness of quality and appearance that blankets most of the city. This is due apparently to the similarity of building sites and the general equality of employment that exists in Lorain. Approximately 60% of the families own their own homes and of these 72% have a value of $3,000 to $7,000; while 18% are above $7,000 and only 10% below $3,000.[34] However, some sections, notably those along the lake shore and some others that front on city parks, have by their more desirable sites, more expensive homes, and greater spacing, been recognized by the city zoning ordinance as type "A" residential sections. But even in these localities, there does not exist the great disparity in residential values, in residential types and in diversity of sites that are so frequently present in other cities. Therefore no separate classification based upon degrees of inequality has been made on Fig. 5. But the disparity in residential desirability will be apparent from the regional residential descriptions.

Another residential classification which is typical of Lorain and which harmonizes with the industrial and commercial

[33]Fifteenth Census of U. S., Ohio Supplement, Classification of Families, Dwellings, etc., for cities and towns, Table 21, p 42.

[34]Fifteenth Census of U. S., op. cit., Table 21, p. 40.

development is one based upon residential types. In Lorain there has been an attempt to decrease the rental costs to the individual family by building two-family, three-family or even four-family (duplex, triplex or quadruplex) houses. There are 1,076, or 12% of the total number of dwellings in Lorain, which are such residences. But in practically all cases, the lots are large and the spacing so well regulated that there is no over-crowded district where slum conditions prevail.

Another general condition that obtains and which is made manifest in the generally improved appearance of the residential sections, is the high percentage of home owners in the foreign population. Although 55% of the population of Lorain is foreign (being those born of foreign parents as well as those foreign born) and 68% of the total number of families in Lorain are foreign, yet these people own 71% of the total number of homes owned in Lorain.[35]

The residential picture can best be presented in parts by a regional treatment.

Residential East Lorain—East Lorain presents the greatest extremes in residential types, desirability and conditions to be found in Lorain. From the small cottages closely set on the narrow lots in front of the American Shipbuilding plant, to the large homes with spacious, landscaped lawns found along the lake shore, are presented the greatest residential contrasts in Lorain. But these are rather localized extremes. Many more homes which occupy a much greater amount of urban land are more typical of East Lorain.

Elsewhere in East Lorain are the average 1½-story bungalow and 2–2½-story cottages of 5–6–7–rooms each that range in value between $3,000 and $7,000. The average type of home occupies approximately 50% of the land devoted to residences and constitutes the basic characteristics of the East Lorain residential section. Practically all houses in this group occupy 50-foot lots with a depth of 120 feet, though the depth varies more often than the width. Houses are placed 15 to 20 feet from the sidewalk with ample spacing for a driveway between and there is enough variety in architectural styles.

This residential section is so isolated by the continuous gorge of Black River that the difficulty of getting to the active sections of Lorain is almost as great as living in the neighboring city of Elyria, eight miles south. The closest street car line is

[35]Op. cit., p. 40.

three-fourths of a mile away, and by road West Lorain is two miles and South Lorain two and one half miles away with no regular means of transportation in either direction.

A few other peripheral residential subdivisions exist in East Lorain, but under existing conditions they are on the outer margins of present maximum development. While these residential extensions lie well inside the city limits, they are undeveloped.

Residential West Lorain—Perhaps the best way to picture the residential conditions of West Lorain is to show the average conditions first, and the variations as exceptions. (Fig. 22).

Approximately two-thirds of the residential land in the entire city is located in West Lorain. Block after block and street after street have the same general appearance (local exceptions will be pointed out later). Houses occupy 50-foot lots with variable depths, the spacing between houses and in front is regularly 15 to 30 feet, and 72% of the homes vary in value between $3,000 and $7,000.[36] Approximately 90% of the residential section is classified as "B" type by the city zoning ordinance. Practically all houses have a small lawn and with gardens on the vacant lots.

However, there is a zonal arrangement that changes the appearance and breaks the sameness throughout. In the inner zone are blocks in which almost all building sites have been fully occupied by buildings with older styles of architecture; while on the residential periphery are new homes with the latest architectural features embodied and often spaced irregularly apart because of the irregular occupancy of the lots. This gives a new and open appearance to the latter, and a more crowded appearance of older buidlings to the former. The relative desirability of residence in either of these zones would depend upon individual selection rather than any great difference in the conditions that obtain.

One other section is possessed with a condition that militates against it for residential purposes. In the first two tiers of blocks west of Broadway, there has been some commercial encroachment. Residences in this location are characterized, not so much by the actual encroachment, but by the increase in value of the land and the consequent alterations that have been made in the residences to make them yield a greater

[36]Fifteenth Census of U. S., Ohio Supplement, Families, etc.; op. cit., Table 21, p. 40.

income. Large residences, and most of the older houses were large, have been converted into flats or apartment buildings. Very often semi-commercial establishments such as beauty parlors, funeral homes, small barber shops, florists, patent medicine agencies, tea rooms, occupy the first floor or a portion of it. Although this commercial encroachment increases the value of the property for commercial purposes, it decreases the desirability of such sections for residential purposes. Also the commercial influence causes a pronounced desire to utilize the yard space to the edge of the sidewalk. Small shoe shops, barber shops, or pop corn stands often appear as separate buildings in the corner of the yard. Throughout the length of this tier of blocks there is this encroachment and various forms of residential modification.

One exception to the average in residential types and conditions, is a superior residential section bordering Lake View Park and the lake front, on West Erie Avenue. Here are located some of the most expensive and attractive homes in Lorain. Although the lots are uniformly 50 feet wide by 120 feet long, houses often occupy two lots. The houses are of brick with spacious landscaped lawns, and are individually placed near the center of the building site. These homes vary in value between $10,000 and $30,000. The site is a level lake plain, which is true of all the residential sections. However, the west side of the city the peripheral location of the subdivision, the open park development, and the relatively short distance to the lake front across the park make this section the most desirable for the wealthier individuals of Lorain.

A second exception, which is as much below the general average of residential condition in Lorain as the former above is a section of only twelve or fourteen blocks. This small section is located between the Nickel Plate railroad tracks and Broadway, and extends south to Seventeenth Street and west to Long Avenue. In the original survey the lots were large, 75 feet, but subsequent development caused these lots to be divided and houses to be erected on half the lot. The houses were small 4–5 and occasionally 6–room, one-story or one and a half story cottages. Moreover, the residences are six to eight feet from the sidewalk, leaving only a miniature lawn with little or no landscaping. This section of the city is occupied mostly by Italians and colored families and is crowded in places.

Residential South Lorain—As referred to in more detail elsewhere, the residential section of South Lorain proceeded according to the plan of the Johnson Steel Company. Here live more than 12,000 people of over twenty nationalities on sixty blocks of urban residential land.[37] Residences were planned and regulated one to each lot with a 50-foot frontage. However, the lots were deep and the houses were spaced uniformly 15–20 feet away from the sidewalk which in turn is laid allowing a 10–15-foot parking. Houses are 1½ to 2½-story cottages well kept and pleasing from the outside. In many places small hedges are set along the property line; while in other sections a small fence incloses the yard. Shade trees set along the parking which faces an exceptionally broad street are impressive because of its spaciousness.

Duplex houses are found in almost every block and usually several in every block. These houses are simply double houses with a single porch divided into two parts and with two entrances, all under one roof. These houses are almost all alike but they have been so interwoven into the entire pattern that they are not conspicuous. Only in two or three blocks does this type of residence predominate. One short block (30th Street and Vine Avenue) where there are twelve such 2½-story brick duplexes is the densest settled block in the city of Lorain. But in spite of the increase in the number of people in each block, the residential appearance is generally a pleasing one. The entire residential section of South Lorain is classified as "B" by the zoning ordinance. This classification makes the section little less desirable than the classification on the lake shore. The most degrading element in the residential section of South Lorain is that some of the east-west residential streets have not been paved but left graded and with gravel surface.

F. OTHER SURFACE UTILIZATIONS OF LORAIN

1. *Public*

Public Functions—Lorain, as a dynamic organism, is called upon to perform manifold public functions. Some are those common to all cities, but a few are in response to local needs.

[37]The population in Sheffield Township in 1930 was 15,873. (Fifteenth Census of U. S., Ohio Population Bulletin, first series, Table 4, p. 21.) Less than 2,500 of these live in the Sheffield Township's portion of East Lorain.

Such important functions as the construction and maintenance of streets and roads; police and fire protection; construction, maintenance and administration of public schools; establishment and operation of an adequate and safe water system; provide and maintain a sewer system; establish and administer parks, playgrounds, bathing beaches, and other recreational facilities; and many other functions of lesser importance are all performed by the City of Lorain. For every public service there is usually some cultural form, and in some cases there are many forms, in the landscape. Very often the number and size of the forms are criteria of the magnitude of the municipal performance. In addition, there are in Lorain cultural forms which are established to perform governmental functions, such as light houses, life-saving stations, a harbor and ship inspection boat, postoffices, etc. While there is a third group of forms that perform public services, but which are semi-public in their maintenance. Churches, hospitals, foreign and domestic clubs, social welfare houses, etc., are such forms in the Lorain landscape. All of these cultural elements have here been interpreted broadly and mapped (Fig. 5) as public utilization because in them the general public participates and by them the people of Lorain benefit.

Schools and Churches—There are in Lorain twenty-two school buildings located, three in East Lorain, seven in South Lorain and twelve in West Lorain. The many school buildings in a city the size of Lorain reflect not only the divided city and its extended plan, with the consequent necessity of placing the public schools in several sections of the city; but it also reflects the many religious sects among the foreign population who maintain parochial schools in connection with the church of their choice.

The aggregate amount of urban land provided for school purposes is in excess of 180 acres or second after parks in the utilization of land devoted to public uses. This is probably a more generous allotment than is found in many other cities: (1) because of the large number of schools and (2) because of the abundance of urban land in Lorain.

The large size and excellent condition of the school buildings, particularly the public schools, reflect the wealth of industrial-commercial Lorain. The taxable assets of the large industrial plants and extensive railroad properties support

proportionately much of the public school system. Moreover, bond issues for constructing new and better school buildings are readily voted by the laboring populace when industrial plants pay a large proportion of the bonded indebtedness. To maintain good school buildings in this way is often possible without the taxes becoming too burdensome as attested by the tax rate of 21.6 mills in Lorain, which is materially lower than the tax rate in most of the neighboring cities.

The emphasis that is placed upon religion in Lorain by the erection of thirty-one churches, some of which are magnificent structures, is occasioned by the very large number of racial groups. There are sixteen churches in South Lorain, fourteen in West Lorain and one in East Lorain. Over one half of the churches are supported by foreign racial groups and many of the large churches operate parochial schools in connection.

Public Services—Lorain's first water system was installed in 1884, when water was pumped from the adjacent lake directly into the city mains.[38] At this point in Lake Erie the water is less than 30 feet deep for two miles out in the lake and lake bottom consists of a very fine blue clay. When agitated by strong winds, the water becomes laden with fine silt, and when mixed with the contaminated organic matter added by Black River, unhealthful conditions prevailed.[39] To complicate and render more difficult the problem of obtaining a pure water supply, the first sewage system in Lorain was installed about eight years after the water system (1892). The sewer emptied into Black River within two-thirds of a mile from the water intake. During this early period Black River earned the sobriquet, "a mudhole, tainted with malaria and typhoid fever."[40] The silt-laden water that was available and the recurring typhoid epidenics in Lorain caused the city to construct in 1897 a filtration plant which had "the distinction of being the first municipal filter plant in the country to be built upon a bacterial guarantee."[41]

These earlier water and sewage systems have been greatly enlarged in subsequent years of city expansion. Now the systems consist of eighty-nine miles of water mains and eighty-eight miles of sewage lines. The same direct system of sewage disposal has been used up to the present time. However,

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[38]Wright, op. cit., p. 293.
[39]Teague, op. cit., p. 29.
[40]Ibid., p. 31.
[41]Wright, op. cit., p. 293.

the city has been ordered by the State Department of Health to provide a sewage disposal plant to improve the condition of the lake water. The present water pumping and filtration plant is located two blocks west of the mouth of Black River. This location partly on the lake-plain level and partly on the lake level facilitates the intake of water, its filtration, and the distribution through the city system.

Due to the low gradient of the sewage system, occasioned by the relatively low relief of the lake plain above the lake, some difficulty is experienced with water backing up in the mains and causing damage by flooding the basements. Particularly during the summer when there is a sudden downpour of 2½ inches or more of rain from thunderstorms.

The construction and maintenance of streets and roads is another important urban function in Lorain sufficient to keep about thirty men employed. The city system includes one hundred and eleven miles of streets, of which seventy-eight miles, or 70%, are paved mostly with brick and asphalt, and thirty-three miles, or 30% are unpaved. Most of the latter are improved by grading and surfacing with gravel, but a few streets, particularly on the periphery of East Lorain, are yet unimproved.

The high percentage of improved streets is encouraged by the soggy nature in wet weather of the lake-plain terrain. Unless streets are improved they become literally impassable for a large portion of the year, and thus may not be used in a semi-improved condition. The relatively great taxable wealth added to Lorain by the heavy industrial plants and extensive railroad transportation properties make possible the improved condition of the urban street system.

Many other municipal and public functions are provided by the City of Lorain, but these are of lesser geographic importance and interest.

Parks and Recreational Facilities—Lorain has an extensive system of parks and playgrounds well distributed throughout the city. The greatest amount of urban land devoted to public use in Lorain is in parks and playgrounds. This is significant in view of the great proportion of open spaces available throughout the city. This may be attributed to the recency of the city's development and the consequent agitation of the public for using urban land in such ways. Also, the city's location along the lake shore provides bathing and recreational possibilities not accorded inland cities.

Two large city parks with piers and bathing facilities are conveniently located along the lake shore one in West Lorain and the other in East Lorain. The greatest handicap in these two locations is that the lake shore is an erosional one and considerable money has necessarily been expended to build protective piers and otherwise render the beaches suitable for bathing.

Another large park containing seventy acres of urban land and yet in a semi-primitive wooded state is located in South Lorain. This park was set aside as a part of the urban developmental plan of the Johnson Steel Company. Later the park was donated to the city by the Sheffield Land Company and was added to the park system. The present undeveloped state of the park is due to the relative abundance of park and playground facilities available on vacant lots and in the open spaces of South Lorain.

Several other smaller parks and playgrounds are provided by the city. Throughout the summer season the parks teem with the cosmopolitan people who take advantage of such facilities.

The natural clayey soil when baked by the hot summer sun provides an excellent play-ground surface that requires little maintenance. The abundance of tennis courts, baseball fields and playgrounds in the city parks is related to the relative ease with which they can be provided and afterwards maintained.

2. *Fishing*

Fishing is Lorain's oldest industry and the only one that has continued as an element in the landscape without interruption through all periods in the city's development. At present it is only of minor relative importance from the standpoint of urban land utilized, number of fishermen employed, and the total annual catch. This industry has long passed its heyday of great "catches" and must be reckoned as a decadent, though persistent, industry.

Three fishing companies now occupy about five acres of land on the west banks of Black River about three-fourths of a mile from the mouth of the stream. Six or eight fishing tugs and twenty–thirty men are employed in the industry during the fishing season. The season begins just as early in the spring as the fishing tugs can get into the open lake water, which averages around the 15th of March and continues until

the 15th of December, or when navigation is no longer possible on Lake Erie. Fishermen recognize two seasons during which time different methods of making the catch are employed.

The continued exploitation of the fish resource has caused an alarming decline in fish production. The present annual catch of the Lorain fisheries, though very erratic, has declined from about 4,000,000 pounds in 1900 to around 1,000,000 pounds annually.[42] The white fish, herring and sturgeon, which were the fish in greatest demand in the early days have now become almost entirely exhausted and are replaced by lake perch and pike. The annual decline in fish production and consequent contraction in the fishing equipment characterize the present industry.[43]

3. *Agricultural and Vacant Land*

Quasi-Agricultural—On the outer fringe of the residential sections of Lorain is an irregularly bordered concentric zone of vacant land. The zone varies in width up to one-quarter of a mile and is most continuous around the residential sections of the city. The zone is made up of acreage tracts varying in size from 9 acres to over 96 acres each. Nor is the zone everywhere within the corporate limits. On the south it avoids the residential sections of West and South Lorain which here extend to the city limits. From all appearances the land is suitable for agricultural purposes or excellent for gardens, but it is left in grass on which milch cows and goats are grazed. This land is held for speculative purposes. The value of the land is around $500 to $1500 per acre, depending upon its location, and is, therefore, too valuable to be farmed. To have growing crops on the acreage tracts would lower their value for subdivision purposes. The land is held without being developed, and, except for occasional small gardens, is allowed to be utilized only as grasslands. After the tracts are sold and have been subdivided they are then used for growing large gardens.

Very little purely agricultural land is found in the city limits of Lorain. In every instance the tracts that are used for agricultural purposes are located outside the quasi-agricultural zone.

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[42]Teague, op. cit., p. 51.

[43]Prior to the World War, the Ranney Company operated seven other fisheries in addition to the one in Lorain. These fisheries were located in Cleveland, Port Clinton, Vermillion, Fairport, Menominee, Ashtabula and Erie. At present the Lorain fishery is the only one operated by this company.

Quasi-Industrial—Just across the river from the steel plant and bordering on Black River are nine rectangular tracts of vacant land. These tracts vary in size between 7 acres and 121 acres each. The aggregate acreage of this land lying partly on the flood-plain and partly on the upland lake-plain is in excess of 610 acres, or 10% of the total amount of urban land. Five of the tracts have exposures on the navigable section of Black River while four have frontages too far upstream. This great block of urban land has industrial potentialities.

Potential Residential—Classified under potential residential is all land in Lorain that has been subdivided for residential purposes but which is yet largely vacant. There are at least fourteen such subdivisions ranging in size from two to fourteen city blocks each. In all subdivisions so classified, at least 50% of the total space, and in most instances 75% or more, is not occupied at the present time and is, therefore, available for residential development. Most of the potential residential land is in East Lorain where isolation, due to lack of transportation facilities across Black River gorge, renders the land less desirable. But in West Lorain the zone of potential residential land is rapidly being occupied to the extent of encroaching upon the zone of quasi-agricultural land outside. The potential-residential land, which is all immediately available for residential purposes, is in excess of one-fourth of the total amount of land now occupied by residences.

G. RELATION OF LORAIN TO ITS REGIONAL SURROUNDINGS

1. *Market Situation of Lorain*

In the foregoing pages the integral organic parts of Lorain have been shown. The following pages will be devoted to a unification of these parts and an explanation of how they function collectively in the regional picture.

The position of Lorain near the population center of the United States and in respect to the markets for the products manufactured in Lorain is a favorable one. Moreover, the intricate railroad network, that emerges from the narrow lowland in northeastern Ohio to radiate fan-like in a southwesterly direction, offers Lorain excellent regional connections with these markets. From Lorain there is a surprisingly large number of optional routes to the same market centers. So

many, in fact, that the practice is for the large shipper to designate the route, including all connections, which the shipment makes.

The two manufactured articles of greatest volume and which move directly to market centers for consumption are pipe and rails. The former is consumed in all sections of the United States where pipe is used, but in greatest volume in the oil and gas fields of the southwest and of California, as well as to oil producing foreign countries. For example, three general routes are used for shipments of pipe to the California oil fields. One is over any one of four railroads to export points on the North Atlantic coast where by boat the shipment is coastwise; another is by rail to the Ohio River, then by barge to New Orleans and by boat through the Panama Canal and to its destination; and the third is an all-rail route to California. However, the first two are used more often than the last because the cost is somewhat less. Not infrequently the time saved in an all-rail shipment is sufficient to absorb the increased costs of such routes Particularly is it true in pipe shipments to the mid-continent oil fields where the cost-difference between all-rail consignments and mixed rail-and-water shipments is less. In any event the shipper or the consignee designates the route over which the shipment goes. The value of steel pipe is sufficiently great to insure its movement from Lorain. The choice in routes is often determined by local circumstances or conditions.

With patented "girder" rails and with "Lorain" shovels the market situation is slightly different. These products, by their specialized nature and patent protection, move to widely distributed markets throughout the world in spite of the shipping costs. However, the central location of Lorain with respect to centers of greatest consumption of these products is favorable to the city.

While for most of the other steel plant products the closeness of Lorain to the iron and steel districts where billets, blooms, skelp, etc., are used, and to the chemical centers where many of the by-products are consumed is an important factor in the distribution of these products of the local plants.

2. *Metropolitan Influence*

That the influence of Metropolitan Cleveland reaches out and encircles Lorain is obvious from the local landscape. The

Lorain branch factories with headquarters in Cleveland; the almost total absence of large wholesale concerns; the direct contact by truck that retail establishments have with Cleveland and the indirect way in which Lorain is dependent upon the rural hinterland; the very much greater volume of traffic over the Lake Road to Cleveland than over other roads from Lorain; the small size of the department and clothing stores of Lorain; and the several daily editions of Cleveland newspapers sold on the streets of Lorain; all suggest the nearness of a metropolitan district with well over a million people. While this nearness may be beneficial to Lorain in many respects, it also stifles the growth of local establishments. No coal dealers in Lorain are engaged in a large way in the coal export trade. Nor do the local merchants carry large stocks of goods from which a wide selection can be made when the very large stores of Cleveland distribute the shopping news in Lorain and vie with each other for the Lorain trade.

The advantages to be gained by such nearness are shown by the recency with which the branch clothing factories have been added to Lorain. Also the recent decision (1932) by the United States Steel Corporation to remove the operations of the Newburg Steel plant of Cleveland to Lorain. This is in part the result of the depression and the consequent contraction, in the interest of economies, that is taking place in the steel-making industry. Because the Lorain plant is modern, and is well situated on a navigable waterway where raw materials are easily obtained; and because the present capacity of the plant is far in excess of the present production, the steel corporation decided to remove the steel-making operations of the Newburg plant to Lorain. The obsolete Newburg plant, valued at $2,239,000, is to be dismantled.[44] The nearness of Lorain to the Cleveland district, where the raw steel will be used in the plant of the American Steel and Wire Company, enables the raw materials to be shipped at a cost of 80 cents per gross ton, which is lower than the cost of producing the same raw material in the Newburg plant. Also, there is the advantage in Lorain of a lower tax rate of $2.16 per hundred dollars value, as compared with $2.76 per hundred in the Newburg location.[45] In the Lorain plant, are enough steel-making equipment and sufficient labor, now idle, to supply the raw materials for the

[44] *The Cleveland Press*, issue of December 7, 1932.
[45] Op cit., p. 174.

American Steel and Wire plant. The move is simply to utilize more fully the modern equipment now installed in the Lorain plant.

Thus the metropolitan sphere of influence funtions in two ways.[46] The centripetal force of Cleveland's retail district tends to attract from and limit the healthy growth of the retail districts in the smaller urban cities; while the centrifugal force of the city's higher taxes, plant obsolescence, and less favorable geographic situation accelerates the industrial function of Lorain.

H. LOCAL PROBLEMS

1. *Depression of 1932*

When a city becomes as specialized and as dependent upon heavy industrial and commercial activities as Lorain has become, a depression like that of 1932 makes a profound imprint upon the landscape. Iron ore imports in 1932 dropped to one-third the normal tonnage; one blast furnace out of five was operated on a reduced draft; steel production was approximately 20% capacity; full time employment ranged between 15 and 20%; and the city was left with little supporting structure. Actual removal of laborers from Lorain was encouraged and resulted in the transfer of many foreign families. Twenty-two hundred families were at one time dependent upon the city and charitable institutions for direct support.

The commercial-retail section reflected the same depressed conditions. Buildings became vacant, merchants became bankrupt, and, except for hordes of unemployed laborers on the streets, the commercial core was inactive. Vacant buildings constituted approximately 25–30% of the total, and in some commercial nuclei of South Lorain 75% of the brick and frame buildings were vacant.

2. *Harbor Improvement Recommendations*

The previous long-period programs of improvement in the Lorain Harbor having been completed, recommendations have been approved by the Chief of United States Army Engineers for two new projects. One calls for the elimination of the two bends in Black River below the Nickel Plate railroad bridge

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[46]See Colby, Charles C. "Centrifugal and Centripetal Forces in Urban Geography." Annals of Association of American Geographers, Vol. XXIII, No. 1, March, 1933.

and the enlargment of the turning basin near the plant of the National Tube Company, and the other is for deepening and improving the channel in the outer and inner harbor. The total expenditure would be $745,000 of which the governmental share would be $600,000. This improvement is expected to put the harbor in a first-class condition to receive large ocean-going vessels that will navigate the Great Lakes when the Great-Lakes-to-St. Lawrence-Waterway is completed. The bends in Black River have long been obstructions in the passage upstream of the long 600-foot boats, which increases the cost of tug-boat service in the river. Two of these have now been removed at a cost of $142,000 and there are now three basins instead of one. These most recent improvements have made the harbor one of the best on the Great Lakes.

With an improved and easily accessible harbor, with a very large amount of potentially industrial land which is now vacant and has frontage on navigable water, with a large supply of labor and with an almost unlimited area over which the city can spread, and with a relatively low tax rate, Lorain, Ohio possesses the essential advantages for continued growth and industrial development.

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Most books on genetics and eugenics are written from the point of view of the specialist. In this volume Dr. Fasten has attempted to write to the beginning student in terms he can appreciate and enjoy. The book covers the usual field of the beginning course in heredity, with considerable emphasis on human inheritance and eugenics. An excellent chapter on acquired characters is included. Unfortunately the student is not introduced to the principles of heredity themselves until nearly half way through the book, and then the many kinds of hereditary behavior are crowded into three or four chapters. Sex-influenced and sex-limited factors are not adequately differentiated, and many of the more specialized types of hereditary behavior are inadequately covered. The book will require much "teaching," but in the hands of a competent instructor should prove satisfactory for the beginning course in genetics.—L. H. S.

Principles of Genetics and Eugenics, by Nathan Fasten. viii+407 pp. Boston, Ginn & Co., 1935.

BOOK NOTICES

The Genetics of Dairy Cattle

Modern genetics has developed modern methods of selection. The work of Heizer, Yapp, Wright and others in perfecting progeny tests has given to the animal breeder a new opportunity for improving production. The Mount Hope Farm has been active in developing and applying such progeny tests to dairy cattle, and the owner of this establishment has now put into book form the principles and practices of progeny selection The result is a readable and inspiring book, beautifully illustrated with colored plates, and containing in addition to the technical applications of progeny tests a fine history of dairy cattle throughout the world. The breeder will certainly want this book, and the geneticist will find it equally indispensable for reference.—L. H S.

Breeding Profitable Dairy Cattle, by E. Parmalee Prentice. xiii+261 pp. Boston and New York, Houghton Mifflin Co., 1935.

Biology for Everyman

Biology for Everyman, a fascinating work of two volumes with an appropriate title, is the crowning work of the late Sir Arthur Thomson, one of the world's truly great biologists. The two volumes contain sixteen hundred pages and over five hundred illustrations, conveniently arranged in four Books. Book I is a systematic discussion of the animal world, from Protozoa up to and including mammals. Book II is a discussion of animal life in general, including such interesting topics as haunts of life, life and the seasons, physiological aspects of animal life, glimpses of animal behavior, sex and heredity, and evolution. Book III is a survey of the plant kingdom and a discussion of plant life in general. Book IV is of probably the greatest interest to the general reader, in that mankind is here considered from such angles as constitutional makeup, race, and relationship to plants, animals and general biology. Biology for Everyman is unique, in that up-to-date biologic information is presented with scientific accuracy, yet in such an interesting and nontechnical style as to be read easily and intelligently by the layman. It is to be highly recommended, not only to the general reader, but also to the professional biologist.—D. C. Rife.

Biology for Everyman, by Sir J. Arthur Thomson. Two vols. New York, E. P. Dutton & Co., 1935.

Prehistoric Animals and Man

Paintings of early man and of prehistoric animals are known to most of us; few of us know the artists who paint them. Among these artists Charles R. Knight is outstanding both for his artistic work and his scientific insight into the forms he paints. Thus his recent volume, "Before the Dawn of History," is very welcome, especially to those who cannot visit the galleries where the paintings hang. This pleasing work contains forty-four halftones of the author's conceptions of prehistoric time from "The World Before Life" to the "Polished Stone-Age Man." Each picture is accompanied by a good descriptive explanation on the opposite page. There are thirty pages of text that deal with various types of fossils and fossil men. It is not a text, however, but a book of plates showing some of the wonderful paintings of Knight. Sad to relate the paintings lose something in the reproductions, which cannot be helped when oils are reproduced in uncolored halftones. We compliment Mr. Knight on collecting these reproductions, and Whittlesey House on publishing them. Knowing Mr. Knight, and being a great admirer of his work, we hope that he will find time to publish more books of this kind so that all his paintings will be available in this usable manner.

Willard Berry.

Before the Dawn of History, by Charles R. Knight. 120+xiii pp. New York, Whittlesey House (McGraw-Hill), 1935.

Principles of Heredity

Fortunately an investigator, active in developing a sound approach to the problems of human heredity, has taken time off to write a beginning text in genetics. This book is as nearly up-to-date as is humanly possible in an infant science just now putting on weight at an alarming rate on a diet of irradiated genes and salivary chromosomes.

Publisher and author are to be congratulated on the refreshing absence of typographical errors in a first edition.

Among the points which commend this work are: the use of examples from human heredity where they serve appropriately to illustrate genetic principles; the division of the subject matter into short, compactly written chapters, each dealing with a specific topic; the realization that the complete understanding of a principle can frequently only be attained as the student develops a background of subject matter, and the consequent specific reference to later chapters where the more extended discussion is to be found; conversely, the frequent reference back to earlier material in forming in the student's mind a synthetic cytological and genetic picture of heredity; the apt use of original illustrations and those drawn from current scientific journals; the clear presentation of the necessary elements of probability, statistical analysis, and the gene-frequency method of studying human heredity; and an understandable discussion of the complex phenomena of modern cyto-genetics.

The reviewer should have welcomed a chapter on the effect of environmental agents on gene activity. However, in his opinion, this is the best beginning text in genetics in its clarity of presentation, aptness of illustration, proper balance and compactness. Such a textbook will do much to establish both the general cultural value of genetics and its necessity as a pre-requisite for the medical course of the near future.—W. P. SPENCER.

The Principles of Heredity, by Laurence H. Snyder. xiii+385 pp., 153 illustrations. Boston, D. C. Heath and Co., 1935. $3.00.

Petroleum

The title of the book would lead one to expect that the author was a petroleum geologist or of some allied profession; rather he is an eminent though elderly botanist. To briefly show the contents: we find first a discussion of the relation of animal oils, especially fish oils, to petroleum. Then taking the Mowry shales of Cretaceous age the author shows to his own satisfaction that these shales extend from Canada into Mexico. He then demonstrates that the petroleum in the shales was derived from fish which were killed by volcanic eruptions to the westward. These same eruptions furnished the necessary volcanic ash to complete the process and bury the fish and make the petroleum. He states that the Mowry shales must have accumulated in from 5,000 to 20,000 years as against Ruby's estimated time of 500,000,000 years. Then he discusses the freshwater Green River shales from the same viewpoint and reaches the same conclusions. The last beds taken up are the marine Miocene oil shales of California where he reaches the same conclusion again. His conception of the origin of petroleum is that it was formed by the action of seismic movements and volcanic eruptions working destruction on great shoals of fish. He firmly believes that extreme temperatures played an important part. Using **Conodonts** as evidence of fresh water conditions he states that most of the Paleozoic, at least those with **Conodonts** in them, are of freshwater origin.

In studying the book and noting the abundant quotations one feels that the author has not studied his subject "written in tables of stone" in the field and has not applied any modern laboratory work. The book appears to be a careful library support for an idea of the past which is considered by the experts of today as untenable. All the present theories on the origin of petroleum are in favor of low temperatures of less than 100 degrees F. Certain of his geologic statements seem to be out of accord with the accepted ideas and some of them are quite the opposite to modern conceptions.—WILLARD BERRY.

The Quantity and Sources of Our Petroleum Supplies, by J. M. MacFarlane. 250+xiii pp. Philadelphia, Noel Printing Co., 1931.

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ANNUAL REPORT

OF THE

OHIO ACADEMY OF SCIENCE

Forty-fifth Meeting

1935

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Affiliated with the American Association for the Advancement of Science

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ARTHUR T. EVANS, term expires 1938

Academy Representatives on the Joint Administrative Board, Ohio Journal of Science

C. G. SHATZER, term expires 1936
E. L. RICE, term expires. 1937

Nominating Committee for 1936

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B. ONDESS L. INMAN
C WILLARD BERRY
D. J. B. BROWN
E. FRANCIS N. MAXFIELD
F. C. E. HOWE
G. G. W. CONREY
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REPORT OF THE FORTY-FIFTH ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE

WILLIAM H. ALEXANDER,
Secretary

INTRODUCTORY

The Forty-fifth Annual Meeting of THE OHIO ACADEMY OF SCIENCE was held at the Ohio State University, Columbus, on Friday and Saturday, April 19 and 20, 1935, under the Presidency of Dr. James P. Porter, of Ohio University, Athens. The campus, the numerous buildings, the excellent equipment, and the generous hospitality of the entertaining institution are well known to most if not all members of the Academy; therefore little need be said along these lines. As on each of the preceding twenty-six occasions when the Academy held its annual meeting at this familiar place the welcoming spirit of the "powers that be" was impressively sincere and generous and the provisions for the needs of every meeting notably ample. The local committee on arrangements under the fine leadership of Dr. Guy-Harold Smith apparently left nothing undone for the welfare of those in attendance.

About 200 members and a large number of visitors were in attendance upon the various meetings, general and sectional, and the annual dinner on Friday night was well attended. Dr. Guy-Harold Smith, chairman of the local committee on arrangements, acted as toastmaster at the dinner, introducing the guests of honor and the speakers of the evening in a most happy manner. President Rightmire, of Ohio State University, extended the cordial greetings of the university, pointing out at the same time in a very impressive way the great service already rendered by Science to humanity, the marvelous services now being rendered and some of the great problems yet to be solved by Science. His was a very forwarding looking address.

The physical and mental setting now seemed excellent for the Presidential Address on "*Our Sciences With Man Left In,*" and the President, Dr. James P. Porter, of Ohio University, in one of his happiest moods, delivered in a most impressive manner the fine address printed elsewhere in these Proceedings. Then followed a most delightful social, get-acquainted hour

in the spacious lounge rooms of the Faculty Club, the final verdict apparently being that "it was good to be there."

Among the outstanding features of the program may be mentioned the invitation address, beautifully illustrated, on "The Canons of the Green, and Colorado Rivers," by Mr. Julius F. Stone, of Columbus; a discussion of "Bobwhite: Song Bird or Game Bird," by Dr. S. Prentiss Baldwin, of the Baldwin Research Laboratory, Gates Mills; a brief discussion of the scientific and technical problems involved in the investigation of the explosion of the State Office Building, by Dr. James R. Withrow, of Ohio State University; a joint meeting of the Section of Psychology and The Ohio Association of Consulting Psychologists, and a Symposium on Chemistry in Biology under the joint auspices of the sections of Botany and Chemistry.

Minutes of the Business Sessions

(Stenographically reported by Wm. H. Howard, Shorthand Instructor, Franklin University, Columbus, Ohio)

First Session: April 19, 1935

The business session was called to order at 9:30 A. M. by the President, Dr. James P. Porter, of Ohio University, in the auditorium of the State Historical and Archaeological Building, Ohio State University, Columbus, Ohio, with thirty in attendance which gradually increased to sixty during the session.

President Porter: The meeting will please come to order. Before proceeding with the business of the morning, I wish to announce that copies of the First and Second Biennial Reports of the State Water Conservation Board are available at the Registrar's table.

At this time I want to make the announcement of the appointment of certain Committees:

The Committee on Necrology—Dr. Willard Berry, of Ohio State University, and Dr. W. H. Shideler, of Miami University. In this connection I want to ask the members to give the names of any who have passed away among our membership, to the gentlemen of this Committee. We have the names of Dr. Wm. A. P. Graham and Dr. James T. Daley.

The Committee on Membership—Dr. W. H. Camp, Dr. Chas. W. Jarvis, and Dr. Wilber E. Stout.

The Committee on Resolutions—Dr. A. W. Lindsay, Dr. F. C. Waite, and Dr. L. B. Nice.

We will now have the report of the Secretary, Mr. Wm. H. Alexander.

The report was read.

PRESIDENT PORTER: You have heard the report of the Secretary; what action do you wish to take?

Motion to accept the report was adopted.

PRESIDENT PORTER: We will now have the report of the Treasurer, Dr. Waller.

DR. A. E. WALLER (After reading report): There are several items I would like to call attention to. The account has been audited and this report is included in the Auditor's report and accepted by the Executive Committee last evening. It was quite evident last year that we were running short; that our shortage was taken care of by the following year's income. Of course, we know we can't proceed forever on that basis. We might be able to do one of several things. We might be able to increase our dues, increase our membership, or reduce our expenses. It is evident right now that our expenses are going higher than our income. While we can carry that for a while, we cannot do so indefinitely.

While the report shows a balance of $594.64 at the beginning of the year, there were outstanding bills of $535.46, leaving in reality a balance of only $59 in the treasury. Consequently, with that in mind, I have asked for some suggestions. The only recommendation we can give is to increase the dues, increase the membership or reduce expenses. We cannot increase the dues. We do believe we can increase the membership; and I believe we can reduce our expenses.

The main item of expense is the printing of the proceedings of our meetings, which I do not believe any one ever reads. We can have them received and authorize the Secretary to preserve them on file available for any one's inspection. I do not believe we actually need to go to print with the proceedings. That would save us about $200. If we could limit the number of pages, we could save something on postage. We have a little variation in the accounts of the Vice-Presidents. Perhaps we could bring those together and put them on the same basis.

While our treasury is intact and we are able to meet our bills, we are doing it with money that is really collectible for

the current year, and still used for the expenses of the previous year, so that is not a very sound condition.

PRESIDENT PORTER: What action do you wish to take on the report?

Motion prevailed to accept and file the report.

PRESIDENT PORTER: The next item of business is election, by ballot, of a Nominating Committee for the coming year, one member from each section, their report to be received at the meeting in 1936.

MR. ALEXANDER: The last few meetings it has been customary just to elect the present Vice-Presidents for the Nominating Committee for the next year. The Secretary has been instructed to cast a ballot for these eight persons. There is no law on this point other than that the ballot is to be in writing.

Motion prevailed instructing the Secretary to cast a ballot for the present Vice-Presidents as the Nominating Committee for 1936.

MR. ALEXANDER: I take pleasure in casting the written vote of the Academy for the following persons as the Nominating Committee for 1936:

ROBERT S. MCEWEN, Oberlin College, Oberlin, Ohio.
ONDESS L. INMAN, Antioch College, Yellow Springs, Ohio.
WILLARD BERRY, Ohio State University, Columbus, Ohio.
J. B. BROWN, Ohio State University, Columbus, Ohio.
FRANCIS N. MAXFIELD, Ohio State University, Columbus, Ohio.
C. E. HOWE, Oberlin College, Oberlin, Ohio.
G. W. CONREY, Ohio Agricultural Exp. Station, Wooster, Ohio.
CLYDE S. ADAMS, Antioch College, Yellow Springs, Ohio.

PRESIDENT PORTER: Are there any items of new business to be brought before the Academy at this time? If not, we shall proceed to Item No. 6, reports on standing committees. We will have the report of the Executive Committee by the Secretary.

Report was read.

PRESIDENT PORTER: You have heard the report of the Executive Committee; what action do you desire to take?

Motion prevailed to accept and file the report.

PRESIDENT PORTER: The next will be the report of the Publications Committee, by Dr. F. H. Krecker, Chairman.

Dr. Krecker made a brief oral statement and promised a complete written report later to be filed with the Secretary. (See page 268.)

PRESIDENT PORTER: This report is before you; what action do you wish to take on the recommendation of the Committee?

Motion was offered to accept the report.

PRESIDENT PORTER: Does this motion refer to both items or the last? I am not clear as to that.

DR. KRECKER: It refers to Article 14 of the Constitution.

PRESIDENT PORTER: That would go over one year.

Motion to accept the report was adopted.

PRESIDENT PORTER: Dr. Krecker.

DR. KRECKER: This coming year the Committee will see to it that the members of the Administrative Board are included on the Publications Committee, otherwise it could be allowed to go as it is for the coming year.

DR. NEALE F. HOWARD: Is it possible to increase the number of Academy members to the same number of members now on the Committee?

MR. ALEXANDER: To change the number on the Joint Administrative Board is not a constitutional change, but if you reduce the number of members on the Publications Committee, that is a constitutional change. The former could be done without delay; the latter requires a year's notice.

A MEMBER: What does that do to the first suggestion he made with reference to the funds?

PRESIDENT PORTER: That no change will be made at present; that is correct, Dr. Krecker?

DR. KRECKER: Yes, sir.

PRESIDENT PORTER: The next item is the report from the Chairman of the Trustees of the Research Funds, Dr. Herbert Osborn.

In the absence of Dr. Osborn, Mr. Alexander read the report signed by Dr. Alpheus W. Smith and Dr. Herbert Osborn.

PRESIDENT PORTER: What do you wish to do with the report?

Motion prevailed to accept the report.

PRESIDENT PORTER: We shall now listen to the report of the Library Committee, Mrs. Ethel M. Miller, Secretary.

Mrs. Miller read her report and commented on some of the items.

PRESIDENT PORTER: What action do you desire to take on the report?

Motion prevailed to accept the report.

PRESIDENT PORTER: We will now hear the report of the

Committee on State Parks and Conservation, by Dr. Edward S. Thomas.

Dr. Thomas read his report and closed by saying: "I am very glad to announce that steps have been taken to have a trained research worker stationed at these areas particularly to study the relationship between these sanctuaries for the protection of wild life. There are more hunters in the field in recent years and have reduced the game 50% among our formerly abundant species, which have become as scarce now as the less abundant species."

President Porter: What action shall we take on the report?

Motion to accept the report was seconded.

Dr. Krecker: I am just wondering what provision there is for association or relationship between the Committee and the higher administrative officers of the State. The thing which makes me ask that question is, during the primary campaign for governor one candidate made the statement he would consult the sportsmen and various people on conservation relative to natural, scientific methods. I have been wondering how much opportunity there has been for impressing our views on conservation upon our state officials. Personally, I would like to see some such channel established. *I would like to suggest that we empower the Conservation Committee to draw up resolutions including the suggestions made by the Committee and send to the Governor, so those in high position will know what we believe.*

President Porter: *Do you wish to make that as a motion?*

Dr. Krecker: *Yes.* I am wondering also if we should adopt the Committee's report about pest hunts. There are many crows in the northwest part of the State. We would hesitate to condemn those hunts. We have had roosts of crows in the neighborhood of Bowling Green of 25,000 to 30,000 crows. There is one in Henry County also. The only way to exterminate them is through pest hunts to reduce their numbers very materially. Those crows make a very heavy toll on the products of the farm—watermelons, chickens and other products. While it is true some useful hawks are killed, I don't think the number is very large.

Dr. Thomas: The Committee does not refer to crow hunts. However, we are bitterly opposed to organized pest hunts. I think data will show that large numbers of beneficial hawks

and song birds are killed, when raiding starling roosts and crow roosts that do not come under the head of general pest hunts. I do not think our resolution would conflict. However, I do question the value to farmers in this state of raiding these crow roosts. These hunts are usually put on in the winter time. I do not think that would relieve the farmers in the summer time. There have been thousands of dollars spent in destroying European starlings. The birds that are in Ohio during the winter months do not remain here through the summer. The starlings we get in the big raids in northeastern Ohio and New York State go back to Ontario during the summer.

PRESIDENT PORTER: Dr. Krecker's *motion to empower the Conservation Committee to draw up resolutions including suggestions made by the Committee and send to the Governor so those in high position will know what we believe*, has been seconded, are you ready for the question?

Motion was carried.

PRESIDENT PORTER: That closes the business session this morning, unless there is something else you desire to consider.

DR. KRECKER: There is still a motion to approve the Committee's report.

PRESIDENT PORTER: That is right, are you ready for the original motion?

Motion carried.

PRESIDENT PORTER: Is Dr. Guy-Harold Smith in the room? We will have an announcement from him later.

The meeting stood adjourned.

Second Session: April 20, 1935

The meeting was called to order at 8:30 A. M. in Room 100, Chemistry Building.

PRESIDENT PORTER: The business meeting will please come to order. The first item of business this morning is the Reports of Special Committees. We will now have the report of the Committee on Election of Fellows, by the Secretary.

Mr. Alexander read the report containing the names of nine who had been elected to Fellowship in the Academy and announced, "It is customary to present each one elected a Fellow with a certificate. These certificates have been duly prepared and signed by the President and Secretary and if any one whose name I called is here, I shall be glad to hand the certificate to him."

MR. ALEXANDER: There is another point, while I am talking, I would like to speak of. Under the Constitution, nominations for Fellowships must be made on a printed form prescribed by the Academy. Occasionally a letter is received suggesting certain persons for Fellows. That is too informal for the Committee to act on. That is why we ask for the names to be put on the prescribed form in order to give the desired information. Remember the mere suggesting of a name for fellowship does not formally nominate. Let us not neglect to attend to this in the formal way. There are many members in our Academy who ought to be Fellows. We cannot use them as officers until they are Fellows. We are losing a lot of excellent talent from our official family because of neglect at this point; we are anxious, therefore, to increase the number of Fellows and thereby increase the available talent for officers and committees.

PRESIDENT PORTER: You have heard the report of the Secretary; what will you do with it?

Motion prevailed to accept the report.

PRESIDENT PORTER: The report of the Committee on Membership will be given by the Secretary.

MR. ALEXANDER: The names of the applicants appear on the blackboard, 22 in all, and all have paid their dues.

PRESIDENT PORTER: These have been approved by the Executive Committee and are now recommended for election to membership in the Academy.

A motion prevailed electing them to membership.

PRESIDENT PORTER: The report of the Committee on Necrology is next; is the chairman of that committee here?

The Committee was given permission to file report later with the Secretary.

PRESIDENT PORTER: The report of the Joint Administrative Board, the Ohio Journal of Science is next. Dr. Rice is coming into the room, so we will pass by this item for the moment. I don't see Dr. Waller who is to report for Save Outdoor Ohio Council.

MR. ROSCOE W. FRANKS: I would rather Dr. Waller would make the report. The Academy voted to withhold paying dues until a satisfactory reorganization of the Council was effected. That reorganization has been made. Mrs. Nora Halter, of Fremont, Ohio, was elected president. There will be a board of directors to determine the policy of the organiza-

tion and to lead the organization. Dr. Raymond C. Osburn, Dr. Wilber Stout, and Mr. Edmund Secrest are on the Forestry Committee. Mr. E. L. Wickliff has charge of scientific research, and Mr. T. H. Langolois is looking after surface water utilization. We have twelve men of that type to take care of the policy of Save Outdoor Ohio Council. I think it would be Mr. Waller's suggestion that the Academy go along this year as a member of Save Outdoor Ohio Council. The Grange has recently come in. We have the Baldwin Research Laboratories, of Gates Mills, Ohio, who volunteered to pay their dues as a member of the organization.

The main thing about the organization as it is now established seems to be a spirit of co-operation and a desire to get together and work out a conservation program. There is no question but that the office of the Conservation Commissioner will co-operate, so we are looking forward for some fine accomplishments in the next year or so.

PRESIDENT PORTER: Is there any action to be taken by the Academy on this report?

MR. FRANKS: Our dues are paid for this year. I don't think we need any action. I have the receipt for our dues.

Motion offered that the report be accepted.

MR. ALEXANDER: Do we have one or two representatives on the Council?

MR. FRANKS: We want to remodel our organization and then make the constitution fit it. The tentative set-up is one delegate, one voting delegate, with $8 dues, 3 delegates, $25. I have been appointed secretary of Save Outdoor Ohio Council and would like to see three members from the Academy of Science, as I feel they will have a real responsibility.

PRESIDENT PORTER: Any more questions. Who is the delegate at present?

MR. FRANKS: Dr. Waller.

PRESIDENT PORTER: Any other questions on this report? The Secretary suggests that we wait until Dr. Waller comes to see if he has anything else to add.

PRESIDENT PORTER: We will now go back to the report of the Joint Administrative Board, the Ohio Journal of Science, and hear from Dr. Bernard S. Meyer, Business Manager.

DR. MEYER: (Read the report.)

PRESIDENT PORTER: Is there any discussion of this report? Motion prevailed to accept the report.

PRESIDENT PORTER: Dr. Waller has now come in, and we will hear from him on Save Outdoor Ohio Council.

DR. WALLER: Last year it was decided to withhold membership dues in the Save Outdoor Ohio Council pending reorganization. This year Mrs. McDonald called a meeting which resulted in such a reorganization. I might explain what the Save Outdoor Ohio Council is. It is made up of representatives from different associations interested in conservation. It is a council for educational and legislative work. During the first few years it was necessary for them to discover what conservation is and how it touches the lives of our people. It was largely a matter of interest on the part of Mrs. George McDonald, of Cincinnati, that the sportsmen and others came together to develop this council. She carried it on as an amateur. As time went on it was found necessary to have a better set-up. Mrs. McDonald was enthusiastic and did a splendid work, but she was not experienced in many of the phases presenting themselves, and consequently they did not always work out as expected. Two years ago the Academy of Science interested itself in the situation as a member organization.

(After reading the report of the Committee on Save Outdoor Ohio Council, Dr. Waller continued:)

It is interesting to see the progress shown by the Council, and it seems to me the Council is worthy of our support, consequently we have taken out one membership in the name of the Ohio Academy of Science. If you wish to send more representatives to the Council meetings, it is possible to do so. At present we have one. The President is Mrs. Nora Halter, of Fremont, and I am certain she will be glad to know that the Academy is interested in supporting the Council. It seems to me we have a number of Ohio Academy of Science members who do not feel it is in harmony with the Academy. We therefore feel that the Council should receive our support and so recommend.

PRESIDENT PORTER: The motion is ready to be voted on to accept the report of the committee.

Motion prevailed accepting the report.

PRESIDENT PORTER: Is there a member of the Committee on Resolutions present to report?

DR. F. C. WAITE: The chairman has not called a meeting of the Committee, but I personally wish to offer the following resolution:

"That the Ohio Academy of Science express its appreciation of the courtesy of the Ohio Archaeological and Historical Society and of Ohio State University and of the heads of various departments of the University for granting the use of rooms and other facilities during the 45th annual meeting of the Academy."

PRESIDENT PORTER: You have heard the resolution.

Motion prevailed to adopt the resolution.

PRESIDENT PORTER: The Secretary suggests that we ask for other resolutions, are there any? (No response.) Is there a member of the Committee on Necrology present now? We passed that report by awhile ago. (No response.)

MR. FRANKS: I have a resolution on pest hunts to offer:

WHEREAS, The emphasis in Pest Hunts is generally placed on predatory mammals, predatory birds and other valuable wild life, instead of upon the obnoxious rodents upon which the predators subsist to a great extent, and

WHEREAS, Information of a scientific character is largely lacking as to the numbers, habits, and economic relationships of predatory mammals in Ohio, and

WHEREAS, Predatory mammals are of value as fur, or as controls for pests, and vary in importance during different seasons and in different sections, and

WHEREAS, There is information of a scientific character sufficient to prove that more than 90 per cent of the predatory birds are of great value in controlling rodent pests, and

WHEREAS, Nineteen of our twenty-two species of predatory birds are now protected by law because of their value to agriculture and conservation; therefore

Be it Resolved, That the Ohio Academy of Science urges the State Division of Conservation to initiate a thorough scientific study of all predatory mammals in Ohio, to determine their distribution, abundance, rate of increase, and food species eaten at various seasons and in various sections, and their economic relationships in the several parts of the State.

Be it Further Resolved, (2) That the State Division of Conservation be encouraged to enforce the laws protecting the valuable birds of prey.

Be it Further Resolved, (3) That the Secretary of the Academy immediately bring this resolution to the attention of the proper persons.

PRESIDENT PORTER: Are there any questions you wish to raise concerning some of the "whereases"?

MR. FRANKS: This may not be stated as clearly as it might be. There are a good many people organizing pest hunts who think they are doing the proper thing. We have no quarrel with pest hunts when they include rats, mice or certain predatory birds. The section of this resolution regarding predatory mammals is similar to the resolution adopted in Michigan.

DR. KRECKER: I take it this carries out the resolution the Academy adopted yesterday. I should think no formal action is necessary.

MR. FRANKS: I am satisfied an action of that kind will be satisfactory to the new Conservation Commissioner.

PRESIDENT PORTER: Any further remarks?

DR. KRECKER: I am thoroughly in favor of the resolution as expressing the attitude of conservationists. The emphasis on pest hunts is always misplaced. They put emphasis largely on hawks and owls instead of putting it on crows and rats. They seem to be ignorant of the situation. I cannot see any objections to this resolution.

PRESIDENT PORTER: The motion is on the adoption of Mr. Franks' resolution.

Motion prevailed adopting the resolution.

PRESIDENT PORTER: Any member of the Committee on Necrology present? (No response.) In the absence of any member of the Committee, what action do you wish to take?

DR. GEORGE D. HUBBARD: I know that Dr. Berry is working on the matter. He is not here to make his report, but he is working on it.

PRESIDENT PORTER: Would it be possible for us to vote an acceptance of the report being prepared?

Motion prevailed to accept the report being prepared by Dr. Berry, Chairman of the Committee on Necrology.

DR. HUBBARD: I am not sure that we know of all the deaths of the past year. I know of but one or two. The Secretary and Mrs. Miller might have a check on that. Older members who do not attend the Academy regularly might be overlooked.

PRESIDENT PORTER: Confer with Mrs. Miller and the Secretary. I think we have now taken care of everything by way of Committee Reports except the Nominating Committee. Has Dr. Howard a report?

DR. HOWARD: (Read his report, signed by all members of the Committee.)

PRESIDENT PORTER: If I understand correctly, nominations from the floor are also in order.

No such nominations being offered, a motion prevailed to close the nominations.

A motion also prevailed accepting the report of the Nominating Committee.

President Porter: The Secretary has just called my attention to a matter that comes very close to me, that Dr. James R. Patrick has not paid his dues. The Secretary suggests that this be left to the Executive Committee. This looks a little like *ex-post facto* business here. I am sure Dr. Patrick will insist that he wants no special favors in this matter. This will be left to the Executive Committee.

Motion prevailed approving the suggestion of the Secretary.

President Porter: Are there any matters of unfinished business? The Secretary says if there is nothing else of unfinished business he has something on his mind.

Mr. Alexander: I realize we have but a few minutes left. There are two or three things I would like to have cleared up. At the last annual meeting and during the year more or less has been said about amendments to the Constitution and By-laws of this organization. As matters stand at the present moment, I do not know whether they have been passed, postponed, or rejected. At the last meeting the Chairman of the Library Committee called our attention to the fact that we had been paying money received from publications over to the Treasurer and said proceeds were being used for the general expenses of the Academy; that during the year she discovered that this money should be paid into the Research Fund; accordingly, the Chairman of the Committee very properly asked that the matter be cleared up.

On motion of Dr. Blake, a resolution was adopted to instruct the Committee to carry out the provisions of the Constitution on this subject, and to prepare and submit an amendment. This was done and a proposed amendment was included in the report of the Executive Committee (q. v.). (Mr. Alexander then read both the existing law and the proposed amendment.) The matter is now squarely up to you; do you or do you not wish to make a change? The Publications Committee seem to favor leaving the by-law as it is. The Executive Committee makes no recommendation.

Dr. Blake: I think we should leave the matter as it is. We were on a Committee to prepare an amendment to the Constitution and By-laws and that was one of the paragraphs I have in mind. The older members will remember the McMillan Fund. After the death of Mr. McMillan, that was increased and we should do everything we can to keep this for the Research Fund.

DR. KRECKER: The Publications Committee had their attention called to this matter by the Secretary not so very long ago. I wrote to the other two members of the Publications Committee and heard from one member, but didn't hear from the other. We didn't get together, but at any rate two of the Committee, myself and one other member, felt the Constitution should remain as it is. I happened to be the only member of the Publications Committee who met with the Executive Committee, and that was the first intimation I had that the change was proposed. Yesterday in my report to the Academy I suggested that as far as the Committee was concerned the matter be deferred one more year. Therefore, I think this action is rather out of place. In any case, I would like for you to agree with the suggestion that the matter be left as it is.

PRESIDENT PORTER: Any further discussion?

————: May I say a word as I am the one not showing up at the Committee meeting? May I make that action of the Committee unanimous? It is my opinion that the matter should stand as it is for the present rather than to make a change.

DR. HUBBARD: I am sure if Professor Osborn were here he would have something to say. We should do what we can to maintain and increase our present Research Fund. The report showed a few dollars less than $2,000. We can't expect more than 4%. This fund is rather small and if anything can be done to increase the amount, we should do it. I am also in sympathy with the Secretary who would like to have it put in Constitutional form. Let it go back to the Committee laboring on it to put it in form for our Constitution.

PRESIDENT PORTER: Is there any further discussion? There being no motion, we will pass to other unfinished business.

MR. ALEXANDER: The question of a constitutional change, then, Mr. President, is referred back to the two Committees?

PRESIDENT PORTER: The Chair so rules.

DR. WAITE: Five years hence we will reach our fiftieth meeting. In view of that fact, I think it should be suggested to the Executive Committee in taking up the meeting places of the Academy, that they should consider what we are going to do the next five years. We don't want it here when the A. A. A. S. comes here. Normally that fiftieth meeting ought to be here. For the preparation of the fiftieth meeting, there will be many things to be done. There ought to be a history written up of the Society at that time. Certainly the Societies

of other neighboring states should be invited at that time, and I think we should have national representatives. A fifty-year record of a Scientific Society should mean something.

President Porter: Are there any remarks on this interesting suggestion from Dr. Waite? (No response.)

Mr. Alexander: I want these things straightened up. Now at the suggestion of our Treasurer, the Executive Committee prepared an amendment to the By-laws. This amendment is referred to you for such action as may seem wise. It is an amendment only in the sense that it is an addition.

(Mr. Alexander read the present provision and the proposed amendment.)

Now that is a new section and offered as Chapter 2 in the By-laws. I would like to have this acted upon.

President Porter: Any questions?

Mr. Alexander: The Treasurer is here and can explain.

Dr. Waller: Each section might have its own meeting and would not have to call on the entire Academy to pay its expenses.

Dr. J. P. Visscher: Probably the principle is very good, but I don't think they will work. In the case of the Geologists' excursion each spring, we need to look up and see who are interested, but certainly we could not ask the people who do not go to defray the expenses of the trip.

Dr. Waite: That plan would bring confusion. People would think they were paying their dues. In other words, in addition to the usual dues they would be solicited for this and then they would say, "I have paid my dues."

Dr. Waller: It would be a thing that each section would take care of as it wished. If the Section wanted a spring meeting, it would look to the members of its own section.

Dr. Carman: Is that to be levied on all Sections?

Dr. Waller: They would have to decide separately what they wanted to do. The ones going on a field trip would naturally pay.

Motion by Dr. Waite that the amendment be disapproved prevailed.

Mr. Alexander: I want to ask that the Committees get together as far as possible and choose their chairmen. When a committee fails to designate a chairman, some one, usually the Secretary, has to do so. Would it not be more satisfactory for each Committee to choose its own chairman?

I desire to announce that the Research Committee's report has been signed by all of the members. The selection of the next meeting place and the fixing of the date should, according to custom, be left to the Executive Committee.

DR. H. B. ENGLISH: During the spring there is usually a congestion of meetings, I presume, because of the closeness of the A. A. A. S. at Christmas time. I do not wish to bring in an amendment, but I would like if it is possible for the Executive Committee of the Academy and the Executive Committee of College Associations to discuss whether one or the other should not meet in the fall while the other meets in the spring. There is about a 50% overlap. I should think the problem of transportation and things of that sort would be a very considerable one for people very far away. I suspect both meetings would gain in attendance and interest. I therefore suggest that the two Executive Committees of these two large Associations might consult as to whether we might meet at more widely different times.

DR. H. H. M. BOWMAN: I desire to suggest that the Academy have its next meeting in Toledo in the fall or spring.

DR. RALPH V. BANGHAM: We would like to have the Academy call at Wooster.

A motion prevailed leaving the matter of the next meeting in the hands of the Executive Committee.

PRESIDENT PORTER: My last word is to thank you for your hearty co-operation, and to declare the meeting adjourned. (Applause.)

THE SCIENTIFIC SESSIONS

GENERAL AND SECTIONAL

The following is a list of the addresses and papers presented at the general and sectional meetings of the Academy as reported to the Secretary, viz.:

1. THE PRESIDENTIAL ADDRESS: Our Sciences With Man Left In, JAMES P. PORTER
2. THE INVITATION ADDRESS: The Canons of the Green and Colorado Rivers . . . . JULIUS F. STONE
3. Some Scientific and Technical Problems Met in Investigating the Explosion of the State Office Building. . . . . JAMES R. WITHROW
4. Bobwhite: Song Bird or Game Bird? . . . . S. PRENTISS BALDWIN
5. The Address of Welcome... . . . . PRESIDENT GEORGE W. RIGHTMIRE
6. The Effect of Temperature on a Mottled Eye . . . . T. C. SURRARRER
7. A Cross-over Modifier in *Drosophila hydei* . . . . WARREN P. SPENCER

8. Four Temperature-Responsive Mutations in *Drosophila funebris*, JAMES NEEL
9. Parasites of Wayne County (Ohio) Fish . . . . . RALPH V. BANGHAM
10. *Daphnia magna* as a Biological Dosimeter for Soft X-rays, GEORGE G. SNIDER AND HAROLD J KERSTEN
11. Time-Temperature Relationships in the Incubation of the Whitefish, *Coregonus clupeaformis* (Mitchell) . . . . . . JOHN W. PRICE
12. Observations on the Development of the Kidney of the Oviparous Fish, *Trichopodus (Osphromenus) trichopterus* . . . . . . E. J. KAROLYI
13. Observations on the Anatomy and Differentiation of the Reproductive Ducts of the Turtle . . . . P. BURWASSER
14. Age as a Factor in the Storage of the Blow-fly Pupae J G. HAUB
15. The Interconversion of Foodstuff during the Metamorphosis of the Blow-fly (*Phormia regina* Meig.):
    I. Respiratory Analysis . . . F. A. HITCHCOCK
    II Chemical Analysis. . . . . J. G. HAUB
16. A Preliminary Report on Oviposition and Fertility in the Blow-fly (*Phormia regina* Meig.) . . . . A. C. MILLER
17 Lake Level and the Fate of Ponds . . . FREDERICK H. KRECKER
18. The Structural Relations of the Human Adrenal-autonomic Complex, D. P. QUIRING
19. The Agglutinogens M and N in New-born Infants HARRIET S. HYMAN
20. Growth in *Daphnia pulex* . . B. G. ANDERSON AND L. J. ZUPANCIC
21. Growth and Maturations in the Parthenogenetic Eggs of *Daphnia magna* . . . . H LUMER
22. The Behavior of a Spider (*Phrurolithus formica*) in the Nests of the Ant (*Crematogaster lineolata*) . . . . . W. M. BARROWS
23. Protocalliphora (Diptera, Calliphoridae) Parasites of Nestling Birds, EDWARD S. THOMAS
24. Pairing in the Ostracod *Entocythere cambaria* Marshall, a Parasite found on Crayfish. . . . . STEPHEN R. WILLIAMS
25. Fluctuations in Numbers of Mammals in a Beech-Maple Climax Community . . . . ARTHUR B. WILLIAMS
26. Some Observations on Adult Insects in Ohio during the Winter .W C STEHR
27. Studies of the Fresh-water Medusa . . . . MRS. A. G LINSCHEID
28. Opportunities for Research at Franz Theodore Stone Laboratory, RAYMOND C OSBURN
29. Distribution of Some of the 179 Species of Birds Known to Breed in Ohio . . . . LAWRENCE E. HICKS
30. A Summary of Research on the European Starling in Ohio, LAWRENCE E. HICKS
31. Factors Affecting the Amount of Reproduction in Passerine Birds, S. CHARLES KENDEIGH
32. The Systematic Status of Ohio Birds . . . . . JOHN W. ALDRICH
33. Ten Years of Wild-Life Research in Ohio . . . . E. L. WICKLIFF
34. On the Microbiology of the Paper Liners of Containers of Peanut Butter and Other Foods . . . . O. T. WILSON
35. Algae of Some Ohio Soils . . . . ELIZABETH E. COYLE
36. Orthogenetic Series in Plants. . . . . .JOHN H SCHAFFNER
37. The Cultivation of Digitalis for Glucosidal Content . FRANKLIN J BACON
38. Additions to the Revised Catalog of Ohio Vascular Plants, JOHN H. SCHAFFNER
39. The Present Status of Botany in the High Schools, PRESIDENT EDWIN E. JACOBS
40. The Vegetation and Dynamics of a Beech-Maple Climax Community, ARTHUR B. WILLIAMS
41. The Annual Increase of Phloem in Some Perennial Conifer Leaves, GLENN W. BLADES
42. Effect of Titanous Chloride on the Formation of Chlorophyll in Zea mays, O. L. INMAN
43. Selective Adaptation to Supports of Twining Vines . . . . H. H. M. BOWMAN
44. The Gastropods of the Hamden Limestone of the Lisbon (Ohio) Quadrangle. . . . . .MYRON T. STURGEON

45. Charaphyta and Conodonts from Columbus-Delaware Contact, WILLARD BERRY
46. Additions to the Bighorn Fauna .... W. H. SHIDELER
47. Vance Well. . . WILBUR STOUT
48. Bitumin Bearing Concretions from the Ohio Shale of the Bellefontaine Outlier .... B. C. FREEMAN
49. Outline of the Section of Geology Spring Field Trip .. WILLARD BERRY
50. Correlations among the Lower Mississippian Formations of Indiana, Kentucky, and Ohio ... . P. B. STOCKDALE
51. The Role of Solution in the Reduction of Interstream Areas, FRANK J. WRIGHT
52. Notes on Insoluble Residues of some Conemaugh Limestones, ROBERT H. MITCHELL
53 Practicability of Rotary Drilling in the Eastern Oil and Gas Fields of the United States ... EDWARD V. O'ROURKE
54. Lacustrine Deposits near Indian Lake in Logan County, Ohio, G. W. CONREY
55. Some Structural Features of the Appalachian Valley in Virginia, ARTHUR BEVAN
56. The Daily Rate of Growth of Nails ...... LINDEN F. EDWARDS
57. Determination of the Cystine Content of Nails .... . EDITH M. MILLER
58 The Composition of Mixed Human Salivas Secreted at Widely Different Rates. ..... N. J. KLOTZ AND J B. BROWN
59. The Dual Function of the Venous Musculature of the Lung of the Frog, H. E HAMLIN, F A WATERMAN AND H. G. KNIERIM
60. Polarized Light—A New Neurological Technique.... . H. E. SETTERFIELD
61. The Influence of the Female White Rat on Bodily Activity of the Male, E. P. DURRANT
62. The Safety Factor in the Adrenal .... FRANK A. HARTMAN
63. The Prognosis in Silicosis .. . . EMERY R. HAYHURST
64. The Clinical Significance of Amyloidosis, LOUIS E. BARRON, WM. T. HAVERFIELD AND G. M. CURTIS
65. Bodily Temperature as it Relates to Nervous and Mental Disorders, CARL W. SAWYER
66. Studies with Artificial Fever in Experimental Tuberculosis. OLGA BIERBAUM
67. The Hematologic Equilibria in Man as Influenced by Artificially Induced Fever, MALCOLM M. HARGRAVES, with the assistance of LUCILLE KESTER, R. N.
68. The Relation of the Non-Filament and Filament Polymorphonuclear Leucocytes, the Reticulocyte and Specific Gravity Changes in the Blood of Rabbits during Emotional Excitement, H. L. KATZ AND L. B. NICE
69. The Specific Gravity Changes in the Blood of Pigeons during Emotional Excitement ....DAVID FROHMAN AND L. B. NICE
70. A Comparative Study of Blood Groups of College Students and Insane Individuals . ...C. A. FREY AND FAYE CAMPBELL
71. The Medico-Legal Applications of the Agglutinogens M and N, HARRIET S. HYMAN
72. Possible Application of Chemical Reactions in the Determination of Pregnancy . ...D. E. BOWMAN, J. P. VISSCHER AND J. W. MULL
73. Importance of Pre-Experimental Attitude or Set in Distraction Experiments .... KENNETH H. BAKER
74. Some Effects of Attitudes upon Personality Inventory Scores, GORDON HENDRICKSON
75. An Effort to Measure Fminine Sociality at the College Level. .J. E. JANNEY
76. Differences between Children with Desirable and Undesirable Overt Behavior . ...C. O. MATHEWS
77. The Switch-Board Learning Apparatus .... WINFORD L. SHARP
78. Rating of Non-Skilled Industrial Workers by a Form Board Test, LORENE TEEGARDEN
79. A Prediction of Typewriting Success .. ..KATHERINE SIMMONS
80. Psychological Problems in Public Employment Offices and in the General Field of Public Personnel . ... LORIN A. THOMPSON

81 Effect of Tobacco Smoke on the Growth and Learning Behavior of the Albino Rat and its Progeny . . .. LOUIS A PECHSTEIN
82 A Study of Attitudes of Beginning Students toward Psychology, H. J. ARNOLD
83. The Predictive Significance of Certain Items in the Application for Admission to Ohio State University . . MAURICE E TROYER
84 A Contribution to the Theory and Technique of Classification, HERBERT A. TOOPS
85. The Spectrum of Nova Hercules N. T. BOBROVNIKOFF
86. Premedical Physics . A. A. BACON
87 The Energy Principle in Elementary Mechanics F. G. TUCKER
88. Tuning an Organ to a Diatonic Scale L. W TAYLOR
89. Numerical Methods in Quantum Theory . . . . . L. H. THOMAS
90. Intensity Relations by the Powder Method of Analysis as a Function of the X-Ray Wave-length . . . . F. C. BLAKE
91. Semi-portable X-Ray Outfit including Metal X-Ray Tube, Pumps, Electrical Equipment and Crystal Spectrograph . . . . C. E HOWE
92. The Million Volt Generator. . . . . W. H. BENNETT
93 Some Improvements in Heat Equipment for the General Laboratory, C. W JARVIS
94. New Demonstrations of Alternating Current Phenomena. LEONARD R. CROW
95. The Construction and Behavior of High Voltage Cylindrical Condensers, F P BUNDY
96. The Infra-red Absorption Spectra of the $X\text{-}Y_4$ Type ALVIN H. NIELSEN
97. The Lake Port at Toledo. . . WALTER G. LEZIUS
98. Population Redistribution in Ohio . .. .GUY-HAROLD SMITH
99. The Aerial Photographic Survey in the Muskingum Valley, MAJOR FRED L. SMITH
100. Announcement of the Field Excursion of the Section of Geology, WILLARD BERRY
101. The Use of Air Photographs in Land Inventory Surveys A. H. PASCHALL
102. Land Use Planning for Erosion Control . . .J S. CUTLER
103. Notes on Ohio Town Patterns . . ALFRED J. WRIGHT
104. Geographic Regions of European Russia . ...GEORGE D. HUBBARD
105. Korea, the Land and the People.. . .. . SHANNON MCCUNE
106. Some Variations in Rainfall in the Salt Creek Watershed, Muskingum County. . .. . WM. D. FENTRESS
107. The Paint Creek Meteorite . . . . . . .KARL VER STEEG
108. Geographic Factors in the Treatment of Tuberculosis in Rutland, Mass.. . .. . GUILBERT R. GRAHAM
109. Stratigraphic Geography . . . . . EUGENE VAN CLEEF
110. The Preparation of Glucosidodihydroxyacetone Penta-acetate, L. C. KREIDER AND WILLIAM LLOYD EVANS
111. The Octenes of Type Three . SIDNEY KUYKENDALL AND CECIL E. BOORD
112. The Teaching of Organic Chemistry . . . . J. R. HARROD
113. The Preparation of Some Tertiary Alcohols Containing the Nonane Chain .... W. R. DIAL AND G. R. YOHE
114. The Action of Molten Sodium Amide on some Simple Aliphatic Amines, G. E SCHMITKONS, F. J. ROBICHAUX AND W. C. FERNELIUS
115. The Fractionation of Cracked Gasolene ...H. J. HALL AND G. B. BACHMAN
116. The Chemical Nature of Tetany .. .. D. E. BABCOCK
117. The Preparation of Some Organic Salts and the Measurement of their Buffer Values . ... W. J. REMINGTON AND H. V. MOGER
118. The Separation of Chromium by Volatilization as Chromyl Chloride, M. H. FILSON
119. Organic Flocculating Agents in the Quantitative Precipitation of Zinc Sulfide. A Proposed Separation of Zinc and Cobalt, J. R. CALDWELL AND H. V. MOYER
120. Demonstration of Surface Energy; Spontaneous Emulsification, JOHN R. CALDWELL
121. The Catalytic Oxidation of Carbon.. . R. F. ROBEY AND J. E. DAY
122. Evaluation of Size Distribution from Sedimentation Data, C. G. DUNCOMBE AND JAMES R. WITHROW

SYMPOSIUM ON CHEMISTRY IN BIOLOGY

123. I. Methods of Studying the Hormones of the Adrenals, DR. F. A. HARTMAN
124. II. The Chemical Basis of Nervous Activity. DR. ALBERT P. MATHEWS
125. III. Chlorophyll and Photosynthesis . ... DR. PAUL ROTHEMUND
126. IV. The Vitamins, with moving pictures taken by Dr. T. S Sutton, showing paralysis due to Vitamin A deficiency in rats, DR. J. F. LYMAN

REPORTS

Report of the Secretary

COLUMBUS, OHIO, April 19, 1935.

To the Ohio Academy of Science:

If "brevity is the soul of wit," this the twelfth annual report of your secretary will have at least one merit of interest. We desire once again to publicly acknowledge with high appreciation the fine spirit of co-operation on the part of all officers of the Academy and of forbearance on the part of the members during the year. As you know, of course, the secretary is by constitutional provision chairman of the program committee, made up of the several vice-presidents of the Academy, and he desires here and now to commend the present committee on the excellence of the sectional programs provided for this meeting. All honor and credit to the vice-presidents!

As you know, the work of the secretary does not end with the adjournment of the annual meeting. The proceedings must be prepared for publication and the printing carefully supervised. Fortunately the secretary is relieved of the work of mailing out the printed proceedings, this work being efficiently taken care of by the library staff at Ohio State University, the university even paying the postage. The duties of secretary are, to be sure, largely routine and when considered individually may seem insignificant and unimportant, but in the aggregate they represent a very considerable amount of time and effort. We have tried to take care of the many calls upon the office during the year as promptly and as efficiently as possible.

A very brief report of the forty-fourth annual meeting was prepared for and published in *Science* and the full proceedings appeared as the July, 1934, number of the OHIO JOURNAL OF SCIENCE.

According to the latest checking of the lists (the Treasurer's list, the Secretary's list and the mailing list of the OHIO JOURNAL OF SCIENCE) the membership of the Academy is about 472. The number varies of course, for several reasons, such as resignation, death, non-payment of dues, etc. These losses are, of course, regrettable, but there is compensation in the fact that new members come in to take the vacant places and great encouragement may be found in the possibility of greatly increasing our numbers if and when the present members are inspired to put forth even a little effort to secure new members. We suggest the following as our slogan for the coming year, viz.:

EVERY MEMBER GET A NEW MEMBER!

In a great state like Ohio, famous for its institutions of learning, we should easily stand first among the State Academies.

Your secretary attended the annual meeting of the American Association for the Advancement of Science in Pittsburgh last December and while there was present at one or two meetings of the Conference of State Academies and much to his surprise was elected Vice-President of the Conference for the ensuing year and according to custom will be the President the following year. For this reason, the secretary asks the honor of representing the Academy on the Council of the A. A. A. S. and at the Conference of State Academies at the next annual meeting to be held in St. Louis, Mo., in December of this year.

Respectfully submitted,

WILLIAM H. ALEXANDER,
Secretary.

Auditor's Report

COLUMBUS, OHIO, March 29, 1935.

Professor A. E. Waller, Treasurer, The Ohio Academy of Science, Columbus, Ohio.

DEAR SIR:—Complying with your instructions, I have completed my examination of the Cash Account and Statement of Receipts and Disbursements of The Ohio Academy of Science for the period from January 16, 1934, to December 31, 1934, and submit the following as my report of the Treasurer's Account:

Cash on hand, January 16, 1934		$ 376 52
Income and Receipts for period:		
Dues	$967 50	
A. A. A. S	121.00	
Library	26 25	
Total Income and Receipts		1,114 75
Total		$1,491.27
Disbursements:		
Wm. H. Alexander, Secretary, Honorarium	$100 00	
Tax on Checks	50	
Charges by Bank for Underbalances	50	
Returned Check	2 50	
Postage, Telegrams, etc	55 50	
Ohio Journal of Science (300)	450 00	
Envelopes, Programs, Letterheads	123.21	
Safe Deposit Box	3 30	
Auditing	15.00	
Expenses;of Vice-Presidents for 44th Annual Meeting	71.97	
Speaker for Annual Meeting	25.00	
Court Stenographer	10.45	
W. H. Alexander, Secretarial Expenses	20 00	
Expenses to Executive Committee Meeting	18 70	
Total Disbursements		896 63
Cash Balance on hand, January 1, 1935		$ 594.64

The Cash Receipts have been traced to the depository and the Disbursements have been verified by cancelled checks and found to be correct.

On December 31, 1934, there were outstanding Accounts Payable to be met from the Academy funds as follows:

Rose McCabe, for Secretarial Services		$ 43 50
Spahr and Glenn, for Printing		5 50
Ohio Journal of Science (191 members)	$286 50	
Ohio Journal of Science (Proceedings)	199 96	
		486.46
Total Payable		$535 46

Should you have met these outstanding payables of $535.46 prior to December 31, 1934, your Cash Balance would have been reduced to $59.18. With membership dues not being paid until late in the year, this balance of $59.18 would not, in the interim, be sufficient to meet the current expenses. This then means that the Current Year expenses are paid from the Following Year receipts, a condition which should not exist. To correct this condition, one of two policies or a combination of both, should be enacted. Either the membership should be enlarged or the annual dues of $2.50 increased or the expenses reduced. I would not, however, consider it wise at this time to attempt much of an increase, if any, in the annual dues. There is, of course, always the possibility of increasing the membership, but until this can be accomplished the only possible procedure seems to be in the reduction of expenses. With this in mind, I have attempted to secure some comparative figures on the larger expense items and find the cost on the major item, "The Ohio Journal of Science," to be quite reasonable. This item does, however, offer a possibility for a considerable saving in the printing cost of this Journal—"The Proceedings." Only a small per cent of your members are interested in the Proceedings of a previous meeting and with the elimination of the Proceedings from your Journal a saving of approximately $200.00 would be reflected.

A considerable variation is noted in the expenses of the various Vice-Presidents. With the co-operation of these gentlemen, a further reduction of expenses could be made.

Other expense items might possibly be reduced as would the item of postage after the elimination of the fifty odd pages of proceedings from the Journal.

While there is a reserve fund in the custody of the Trustees of the Research Fund of the Ohio Academy of Science, an effort should be made to at least hold this fund intact rather than permit any condition whereby the same might be reduced or depleted.

While I have not had access to the records of the Trustees of the Research Fund of the Ohio Academy of Science, I am informed by the Ohio National Bank that on December 31, 1934, there was a cash balance on deposit in this Fund of $200.40. This balance January 16, 1934, was $237.14, reflecting some small disbursements during the period.

Respectfully submitted,

JAS. P. CORNETET,
Certified Public Accountant.

Report of the Executive Committee

COLUMBUS, OHIO, April 19, 1935.

To the Ohio Academy of Science:

The current Executive Committee has held three formal meetings during the year, one on November 3, 1934, one on January 26, 1935, and the third are last evening, April 18, 1935. All were held in Columbus and the first two well attended.

At the first meeting, after some discussion and a frank statement by the Editor-in-Chief of the Journal of Science, and in view of the Academy finances it was unanimously agreed that it would be unwise to grant the request of the Administrative Board for a special grant of $500.00.

The resolution introduced by Dr. F. C. Blake and passed by the Academy at the last annual meeting relative to an amendment to the Constitution and By-Laws regarding the disposition of funds received from the sale of publications was considered at this meeting and it was decided to prepare an amendment for subsequent approval of this and the Publications Committee's diverting said funds, together with the interest, from the invested research funds to aid in the publication of research. The following amendment to the By-Laws is suggested, viz.:

CHAPTER VII—*Research Fund.* Paragraph 1 amended to read:

The Research Fund shall consist of donations made in the aid of research and of sums paid in commutation of dues according to By-Laws, Chapter I, Paragraph 1. The interest received from invested research funds and all moneys received from the sale of Academy publications shall be used to aid in the publication of research.

The following applications for membership in the Academy were approved and are recommended for final election by the Academy, viz.: Richard P. Fowler, Guilford J. Ikenberry, J. F. Lyman, Victor A. Norling and R. K. Salisbury.

At the suggestion of the Treasurer, the Secretary was asked to prepare an amendment to the By-Laws authorizing the Vice-President of any Section so desiring to collect funds from the members of his Section to defray expenses of special meetings, field trips, etc.

At the second meeting of the committee the Secretary, as requested at the first meeting, submitted the following amendment to Chapter II:

PARAGRAPH 3. *Expenses of Special Section Meetings or Excursions.*—Any Section may by vote authorize its Vice-President to collect from its members funds necessary to defray the expenses of special meetings, field trips, or excursions, said section may wish to sponsor.

Paragraph 3 to be numbered 4.

The committee voted unanimously to recommend the passage of said amendment to the By-Laws.

At the second meeting, the following applications for membership in the Academy were approved and same are now recommended for final election by the Academy, viz.: William T. Bean, Leonard R. Crow, Mary Dora Rogick, and Charles A. Trimble.

At this meeting also the President of the Academy was made

a committee of one to make a thorough investigation of the printing costs of the Proceedings of the annual meeting and make report at the next meeting of the committee.

At the second meeting of the Committee the Secretary was asked to prepare and submit at next meeting a suitable amendment to the Constitution and By-Laws providing for a new class of members to be known as "Student Members" as suggested by Doctor Evans.

The third and last meeting of the committee was held at the Deshler-Wallick Hotel on the evening of April 18, 1935, with a rather small number present. In the absence of the secretary, Dr. Raymond C. Osburn acted as secretary.

Owing to the small attendance of the committee no action was taken on the suggested amendment to the Constitution and By-Laws providing for "Student Members." It was thought best to lay the matter before the Academy either for further consideration by the Executive Committee, or for action by the Academy at this meeting.

The same course was taken in the case of the proposed amendment concerning the Research Fund; that is, referred to the Academy without recommendation.

The applications for membership in the Academy of the following persons were received, favorably considered and are recommended for final election, viz.: Edith Marie Miller, Thomas T. Frost, and Edwin E. Jacobs.

Respectfully,

WILLIAM H. ALEXANDER,
Secretary.

Report of the Library Committee

COLUMBUS, OHIO, April 19, 1935.

To the Ohio Academy of Science:

The work of the chairman of this committee has been of the customary routine nature, such as correspondence, the care of the mailing list, claiming issues of periodicals that somehow failed to arrive, posting out issues of our publications, and the sales of publications.

Eleven new exchanges have been secured, four in this country, two in South America, three in Europe, one in Asia, and one in Africa. This makes a total of 382 exchanges on the mailing list.

It has been several years since a systematic check was made upon the exchanges to ascertain whether they are being received regularly at the Ohio State University Library. This project is now being carried on but not enough has been done for a report to be made at this time.

The report last year stated that the stock of the Ohio Naturalist and of the Ohio Journal of Science had been cleaned and wrapped and inventory taken but that the exact figures were not yet available at the time of the meeting. However, it was estimated that they would range from 300 sets of some of the volumes of the Ohio Naturalist down to 50 sets of a few of the volumes of the Ohio Journal of Science. The actual figures show that one volume of the Ohio Naturalist has one hundred sets, but that all the others have from 211 to 471 sets.

The stock of the Ohio Journal of Science varies greatly, from 27 sets each of volumes 24 and 25, to 370 sets of volume 18. Nine other volumes have 100 or more sets and eight volumes have fewer than 70 sets. There are no complete sets of volume 22, as the stock of number 6 of that volume was exhausted years ago. The scarce numbers of the stock of the Ohio Journal of Science at the present time are as follows: Vol. 23, No. 5, September, 1923; Vol. 24, No. 1, January, 1924; Vol. 25, Nos. 3 and 4, May and July, 1925; Vol. 26, No. 3, May, 1926; Vol. 27, Nos. 2 and 3, March and May, 1927; and Vol. 30, No. 5, September, 1930. If anyone who reads this report in the July issue of the Ohio Journal of Science has any of these scarce issues which he does not care to keep, they will gladly be taken back to be put into stock.

A corrected membership list of the Ohio Academy of Science was sent a week ago to "Scientia" in Milan, Italy. This is a new publication and the general secretary asked recently for a complete list of the names and addresses of the members in order that specimen copies could be posted to each one.

If one can judge from the sales of publications for the past year, the times are getting a little better. While the number of sales and the total amount did not approach those of a few years ago, yet a substantial increase was made over the preceding year. Exactly fifty items were sold in twenty-six sales. Eighteen sales were made to people in Ohio and eight to persons living in Utah, Oklahoma, Missouri, Tennessee, Indiana, Pennsylvania, and New York. The "Odonata of Ohio," by Dr. D. S. Kellicott, and the "Agaricaceae of Ohio," by Dr. W. G. Stover, headed the list, followed closely by Max Morse's "Batrachians and Reptiles of Ohio." Four copies of this last named paper were purchased by the Toledo Public Library and five copies of Dr. Stover's "Agaricaceae of Ohio" were bought by the library of the University of Cincinnati. The sales amounted to $32.30, of which $26.25 was given to the Treasurer before December 31st, leaving a balance on hands of $6.05. This sum has been given to him since the first of the year and will appear in his report for 1935.

For several years a formal financial statement of the sales account has been given in this report. This practice was discontinued last year as the account was too small to be considered apart from the account of the Treasurer. The statement for 1934 has been duly made and is on file for the purpose of record. There is in the bank at the present time the sum of $29.29. No money is yet being paid out on running stock certificates except dividends, but the building and loan company expects to be permitted to pay on such accounts before very long.

The stock of Special Paper No. 6, Dr. Lynds Jones' "Birds of Ohio," is now reduced to twenty salable copies. The members of the library committee recommend that no more copies be sold separately or sent in exchange but that all be kept for future use in complete sets of the Proceedings.

Respectfully submitted,

ETHEL MELSHEIMER MILLER,
Chairman.

Report of the Trustees of the Research Fund

COLUMBUS, OHIO, April 20, 1935.

To the Ohio Academy of Science:

The research funds of the Academy have not changed greatly during the past year. A grant of $100 was made to assist in the purchase of apparatus used in the Department of Chemistry at the Ohio State University, the total cost being $1,400 and the apparatus is now available to members of the Academy who may have occasion to use it.

The receipts January 1, 1934, to December 31, 1934, were $63.28 and the disbursements, as stated above, $100.

SUMMARY

Balance Checking Account January 1, 1934	$237.14
Receipts from Interest, etc	63.28
Total	$300 42

DISBURSEMENTS

Grant for part cost of Chemical Apparatus	$100 00
Check Charge	02
Balance in Checking Account	200.40
Total	$300 42

Receipts since January 1st bring our balance on checking account to $209.40 as shown by bank statement.

The securities held stand as in last year's report, listed at $1,737.50, which with the bank balance as of January 1, 1935, would give total assets of $1,937.90.

Respectfully submitted,

HERBERT OSBORN,
GEO. D. HUBBARD,
Trustees.

Report of the Publications Committee

COLUMBUS, OHIO, April 19, 1935.

To the Ohio Academy of Science:

In fulfilling its designated duties of attending to the publications of the Academy, the Committee made inquiries in various directions regarding manuscripts which might be suitable for publication by the Academy. The inquiries disclosed no manuscripts, and none came to the attention of the Committee through other channels.

A duty was laid upon the Committee by the following motion, offered by F. C. Blake, and approved by the Academy at the 1934 meeting:

"That the section of the constitution relative to money received from the sale of publications of the Academy being credited to the Research Fund be referred jointly to the Executive and the Publications Committee with instructions to prepare and present an amendment to the constitution of the Academy for action at the next annual meeting, if in the judgment of the joint committee it seems wise to do so, this motion to serve as notice of a proposed change."

Upon consideration the Committee sees no reason for amending the provision of the constitution referred to, and feels that hereafter the provision should be followed. A joint meeting of the Publications Committee and of the Executive Committee for Thursday evening, April 18, for consideration of Mr. Blake's motion was suggested by the Academy secretary, Mr. Alexander. At this meeting, which incidentally was poorly attended by both committees, an amendment suggested by the Executive Committee and approved by it at a previous meeting was presented for joint consideration. Since the Publications Committee had not learned of this suggested amendment earlier and since neither committee was sufficiently represented for an adequate discussion of the different viewpoints and for possible joint action, the Publications Committee feels that the matter should be deferred until the next meeting of the Academy to allow the two committees to give the matter their joint attention.

The Publications Committee wishes to suggest a change in the practice of the Academy with respect to that committee and the Academy representatives on the Administrative Board of the Ohio Academy of Science. Since the duties of the two groups are of much the same character and in neither case especially burdensome, we suggest that hereafter the Publications Committee serve also as the Academy representatives on the Ohio Journal of Science. As a matter of fact the by-laws say:

"The publications of the Academy are in charge of the Publications Committee."

Since the Ohio Journal of Science is the official publication of the Academy, the connection between the Administrative Board and the Publications Committee appear rather obvious.

The situation can be met by amending Article 4, Item 14. This now reads:

"14. *Duties of Publications Committee*.—The Publications Committee shall have charge of the preparation and publication of the Annual Report and of such other papers as may be considered by them desirable to have printed."

The Committee suggests the following change in this item, and offers it as an amendment to the constitution to be acted upon at the next meeting of the Academy.

"The Publications Committee shall serve as the Academy representatives on the Board of the Ohio Journal of Science, and shall have charge of the preparation and publication of the Annual Report and of such other papers as may be considered by them desirable to have printed."

Since the Administrative Board is composed of two members each from the Ohio State University and the Ohio Academy of Science, such a change would involve either (a) reducing the Publications Committee to two individuals, or (b) increasing the representation on the Administrative Board to three members from each group. Since the number of members on the Publications Committee is set at three by constitutional provision, the second alternative seems to be the simpler.

Until final action can be taken on the proposed amendment, the situation could be met and the arrangement given a trial by electing the present Academy representatives of the Administrative Board as members of the Publications Committee.

Respectfully submitted,

J. ERNEST CARMAN,
STEPHEN R. WILLIAMS,
FREDERICK H. KRECKER, *Chairman.*

Report of the Members of the Joint Administrative Board of the Ohio Journal of Science

COLUMBUS, OHIO, April 20, 1935.

To the Ohio Academy of Science:

The only meeting of the Joint Administrative Board of the Ohio Journal of Science since the last report was held on the evening of April 18, 1935. Present were all members of the Board, Messrs. Rice, Shatzer, Transeau, and Blake, the Editor and Business Manager of the Journal.

Upon motion Dr. L. H. Snyder was re-elected Editor and Dr. B. S. Meyer, Business Manager of the Journal for the coming year.

Upon motion Dr. E. L. Rice was re-elected Chairman and Dr. B. S. Meyer, Secretary of the Board for the coming year.

The Business Manager presented a financial report for the year 1934, as follows:

THE OHIO JOURNAL OF SCIENCE, FISCAL YEAR 1934

RECEIPTS	
Balance from 1933	$ 278.42
University grant	650.00
Ohio Academy of Science	736.50
Ohio Academy of Science, Proceedings, 1934	199.96
Subscriptions	104.03
Sale of Back Numbers	27.80
Author's Payments for Plates and Publication of Papers Out of Order	214.18
	$2,210.89
EXPENDITURES	
Spahr & Glenn Co., Printing Volume 34	$1,421.79
Bucher Engraving Co.	273.84
Postal Charges	148.74
Envelopes and Stationery	35.10
Clerical Assistance	5.00
Reprints	8.50
Federal Check Tax	.60
	$1,893.57
Balance on Hand, Feb. 25, 1935 (Huntington National Bank)	317.32
	$2,210.89

Upon motion the Business Manager's report was accepted and placed on file. This report was audited by a committee consisting of Profs. Rice and Shatzer and found to be correct.

Motion passed that beginning with the current year's report that the Business Manager submit his accounts to a professional audit before presenting them to the Board.

The Board then inspected an exhibit demonstrating the stages in the manufacture of the Journal, as prepared by the Editor for the present meeting of the Academy. A motion was passed expressing approval of the exhibit and commending the Editor for undertaking the labor of preparing it.

Respectfully submitted,

B. S. MEYER, *Secretary,*
Joint Administrative Board of the Ohio Journal of Science.

Report of the Save Outdoor Ohio Council Committee

COLUMBUS, OHIO, April 20, 1935.

To the Ohio Academy of Science:

Two years ago the Ohio Academy of Science did not maintain a membership in the Save Outdoor Ohio Council. It was understood that this membership was to be renewed following the organization of the Council. On January 2nd Mrs. McDonald called a meeting of the Save Outdoor Ohio Council for the purpose of reorganization. Because of its confidence in the work of the Council the Academy has taken out its membership immediately. The work of Mrs. McDonald is quite worthy of support but unfortunately she has been unable to continue as President due to poor health and absence from the State. The following officers of the Council were elected at the reorganization meeting:

BOARD OF DIRECTORS

MRS. GEORGE McDONALD, *Honorary President*	Wyoming, Ohio
MRS. NORA HALTER, *President*	1319 Birchard Ave., Fremont, Ohio
MR. T. D. PEFFLEY, *First Vice-President*	P. O. Box 891, Dayton, Ohio
MR. HARRY N. KATZ, *Second Vice-President*	2384 Indiana Ave., Columbus, Ohio
MR. ROSCOE W. FRANKS, *Executive Secretary*	3040 Neil Ave., Columbus, Ohio
MR. JOSEPH C. GOODMAN, *Treasurer*	471 East Broad St., Columbus, Ohio

The purpose of the Council is to call together all of the agencies in the State interested in conservation. The plan is to co-operate both conservation education and conservation legislation. Various Chairmen of the Committee are as follows:

Chairman of Education Committee:
DR. RAYMOND C. OSBURN, Head, Dept. of Zoology, Ohio State University.

Chairman of Conservation Research Committee:
MR E. L. WICKLIFF, Chief, Bureau of Scientific Research, Ohio Division of Conservation, Columbus, Ohio.

Chairman of Forestry Committee:
MR. EDMUND SECREST, State Forester, Wooster, Ohio.

Chairman of Surface Water Utilization Committee:
MR. T. H. LANGLOIS, Chief, Bureau of Fish Propagation, Ohio Division of Conservation, Columbus, Ohio.

Chairman of Water Conservation Committee:
MR. DAVID C. WARNER, Executive Secretary, Ohio Water Conservation Board, Columbus, Ohio.

Chairman of Geology Committee:
DR. WILBER E. STOUT, State Geologist, Ohio State University.

Chairman of Game Management Committee:
DR. LAWRENCE E. HICKS, Chief, Division of Game Conservation, U. S. Erosion Service, Zanesville, Ohio.

Chairman of Archaeological and Historical Sites Committee:
MR. H. R. MCPHERSON, Curator of Parks, Ohio State Museum, Columbus, Ohio.

Chairman of Recreation Committee:
MR. OLIVER HARTLEY, Secretary, League of Ohio Sportsmen, Columbus, Ohio.

Chairman of Roadside Landscape Improvement Committee:
MR. DALLAS D. DUPRE, Landscape Architect, Ohio Dept. of Highways, Columbus, Ohio.

Chairman of Publications Committee:
MR. WALTER A. TUCKER, Editorial Staff, The Columbus Dispatch, Columbus, Ohio.

Chairman of Legislative Committee:
MR. J. F. ATWOOD, Attorney, 33 N High St., Columbus, Ohio.

Office of the President:
1319 Birchard Ave., Fremont, Ohio.

It therefore seems that this Council is taking shape in a manner worthy of the enterprises for which it stands and I recommend your support of the organization.

Respectfully submitted,

A. E. WALLER.

Report of the Committee on the Election of Fellows

COLUMBUS, OHIO, April 20, 1935.

To the Ohio Academy of Science:

The Committee on the Election of Fellows met at the Deshler-Wallick Hotel on Thursday evening, April 18, 1935, for the purpose of considering nominations to fellowship in the Academy. The following persons whose nominations were found to be in proper form, satisfactorily supported by documentary evidence and countersigned by two fellows in good standing, each having received the required three-fourths vote of the Committee, were declared duly elected to Fellowship in the Academy, viz.:

DR. MARY AUTEN, Ashland College.
DR. EARL CLARK CASE, University of Cincinnati.
DR. FRED FOREMAN, Oberlin College.
DR. REUEL B. FROST, Oberlin College.
DR. AMOS HENRY HERSH, Western Reserve University.
DR. HERRICK LEE JOHNSTON, Ohio State University.
DR. SAMUEL CHARLES KENDEIGH, Baldwin Bird Research Laboratory.
DR. HARVEY V. MOYER, Ohio State University.
DR. IRA TEMPLIN WILSON, Heidelberg College.

Respectfully submitted,

WILLIAM H. ALEXANDER,
Secretary.

Report of the Committee on Necrology

Sketch of the Life and Work of Dr. Frank Carney

(Prepared by Prof. Geo. D. Hubbard, Oberlin College, at the request of the Committee.)

Frank Carney was born at Watkins, New York, March 15, 1868, son of an internationally minded farmer and student of current history. He studied and later taught in Starkey Seminary and in Cornell University. In 1895, after three years of regular work supplemented by work in the summer sessions, he was given Cornell's A.B. degree. He taught in Keuka Institute (1895–1909) and in the High School of Ithaca, New York. While vice-principal of the Ithaca High School, 1901–04, he served as assistant in Geology in the University one year and as instructor in the Cornell Summer School of Geography each summer.

In 1904 Mr. Carney was appointed Professor of Geology and Geography at Denison University, a position he held until 1917. Always studying and working in the field, he completed the requirements for the doctorate and was given that degree by Cornell University in 1909. During the Denison period Doctor Carney was called upon often for lectures and addresses; for three summers, 1909–11, he taught at the University of Virginia; in 1912 at Chicago; and for three summers, 1914–16, at Cornell University. During the year 1912–13 he was acting professor at Michigan and declined a permanent appointment there. While at Denison he was also an Assistant Geologist on the Ohio Geological Survey, 1907–17.

In 1917 Dr. Carney became Chief Geologist for the National Refining Company and soon moved to Texas. For eleven years he resisted the call to return to teaching, the work he loved most of all, but in 1928 he joined the faculty of Texas Christian University and the next year became Chairman of the Department of Geology and Geography of Baylor University at Waco, Texas, a place which he held until his death in December, 1934.

Doctor Carney was always a public-spirited man, interested in the progress of his profession, education, of his science, geography, and of his religion, his family and his community. He was always a forceful, clear, stimulating speaker and had many opportunities to speak, especially after his removal to Texas. He began writing for publication in 1901 and published forty-four scientific papers during the next seventeen years in the leading journals of his field. All these were the product of a lucid pen and scholarly mind. No papers appeared from 1917 to the end although his professional interests seem to have been as keen as ever. His executive work and restrictions growing out of that responsibility seem never to have dampened his ardor for research nor his scholarly thoughtful habits.

Professional recognition of his scientific work came in his election to Fellowship in the Geological Society of America, American Association for the Advancement of Science, and Ohio Academy of Science (president, 1909); to membership in the Association of American

Geographers (vice-president, 1915), American Association of Petroleum Geologists. American Institute of Mining and Metallurgical Engineers, Seismological Society of America, Michigan Academy of Science, Society of Economic Paleontologists and Mineralogists, Southwestern Social Science Association (chairman, Human Geography Section, 1934), Texas Academy of Science, Texas Geographic Society, C. L. Herrick Geological Society and the Sigma Xi.

But Professor Carney's most permanent work and finest products came out of his teaching. He loved it and brought everything to it necessary to make it successful. His students and colleagues, in speaking of his classroom and conference work, describe him as "personal, friendly, sympathetic, scholarly, inspiring, frank and honest, of sound judgment, a prodigious worker, able, lovable and worthy of every confidence and element of respect accorded him." Out of his thirteen years at Denison have come seventeen professional geologists and geographers. His personality has vividly impressed itself upon many more. In Carney's going we lose a friend, an inspiring teacher, a scholarly, exact writer, and a Christian gentleman.

Report of the Membership Committee

COLUMBUS, OHIO, April 20, 1935.

To the Ohio Academy of Science:

Your Committee on Membership has received and examined 22 applications for membership in the Academy, have found them in proper form, fees for one year paid and now recommend their election to full membership in the Academy, viz.:

BEAN, WILLIAM T., 733 Liberty St., Franklin, Penn.
BOBROVNIKOFF, N. T., Perkins Observatory, Delaware, Ohio.
CROW, LEONARD R., 1110 N. Eighth St., Terre Haute, Ind.
FOWLER, RICHARD P., 224 W. College St., Oberlin, Ohio.
FREEMAN, B. C., 225 E. Blake Ave., Columbus, Ohio.
FROST, THOMAS T., M. D., Ohio State University, Columbus, Ohio.
HAHNERT, WILLIAM F., Ohio Wesleyan University, Delaware, Ohio.
HARTMAN, FRANK A., Hamilton Hall, O. S. U., Columbus, Ohio.
HAMBLETON, J. C., 380 W. Eighth Ave., Columbus, Ohio.
HAMRE, HAROLD T., Wittenberg College, Springfield, Ohio.
IKENBERRY, GUILFORD J., 2221 Blake St., Berkeley, Calif.
JACOBS, EDWIN E , Ashland College, Ashland, Ohio.
KERSTEN, HAROLD JOHN, University of Cincinnati, Cincinnati, Ohio.
LYMAN, J. F., Townshend Hall, O. S. U., Columbus, Ohio.
MILLER, EDITH MARIE, 54 E. Longview Ave., Columbus, Ohio.
NORLING, VICTOR A., 612 Lawrence Ave., Girard, Ohio.
PASCHALL, ALFRED H., 139 Putnam St., Zanesville, Ohio.
ROGICK, MARY DORA, College of New Rochelle, New Rochelle, N. Y.
SALISBURY, R K., Terrace Park, Ohio.
STURGEON, MYRON T., 259 W. Second St., Salem, Ohio.
TRIMBLE, CHARLES A., O. S. & S O. Home, Xenia, Ohio.
WAREHAM, R. T., Department of Botany, O. S. U , Columbus, Ohio.

Respectfully submitted,

W. H. CAMP, Chairman,
CHARLES W. JARVIS,
WILBER E. STOUT,
Committee.

Report of the Nominating Committee

COLUMBUS, OHIO, April 20, 1935.

To the Ohio Academy of Science:

The Committee on Nominations begs to submit the following report, viz.:

President—WALTER H. BUCHER.

Vice-Presidents—

A. *Zoology*—DAVID F. MILLER.
B. *Botany*—GLENN W. BLAYDES.
C. *Geology*—MISS GRACE ANN STEWART
D *Medical Sciences*—CHARLES A. DOAN.
E. *Psychology*—JAMES R PATRICK.
F. *Physics and Astronomy*—CHARLES W JARVIS.
G. *Geography*—GUY-HAROLD SMITH.
H. *Chemistry*—K. G. BUSCH.
Secretary Chemistry Section—W. C. FERNELIUS.

Secretary—WILLIAM H. ALEXANDER.

Treasurer—A. E WALLER.

Elective Members, Executive Committee—JAMES P. PORTER AND EUGENE VAN CLEEF.

Trustee, Research Fund—HERBERT OSBORN.

Publications Committee—E. L. RICE, C. G. SHATZER AND R. V. BANGHAM.

Library Committee—F O GROVER

Committee on State Parks and Conservation—G. W. CONREY, E L. WICKLIFF AND ARTHUR T. EVANS.

Joint Administrative Board, The Ohio Journal of Science—E. L. RICE

Respectfully submitted,

NEAL F. HOWARD, Chairman,
ORVILLE T. WILSON (N. F. H.),
ROBERT A. KEHOE (N. F. H.),
EDMUND M. SPIEKER (N. F. H.),
RICHARD S. UHRBROCK,
R. L. EDWARDS,
RODERICK PEATTIE (N. F. H.),
WM. LLOYD EVANS.

Presidential Address

OUR SCIENCES WITH MAN LEFT IN

JAMES P. PORTER,

Ohio University

Mr. Chairman, Ladies and Gentlemen:

An International Congress was in session at one of our great eastern universities. The president of this university, Yale, was observed standing outside the entrance to the large dining hall carefully checking the speed and efficiency with which his guests were being served. To be sure the time was that of the late summer vacation. Could not some minor executive have followed up this attempt to serve the individual members of this great organization? Not to the full satisfaction of this great administrator who for many years earlier had been head of a department, the work of which emphasizes, if it does not require, attention to individuals by individuals. His democratic leadership is attested by the fact that in any significant proposed change those who are likely to be his severe critics and opponents are heard from early. The institution over which he presides has thus far been one of a very few to organize various related departments into an Institute of Human Relations. Here some of our sciences at least are determined to leave man in.

The primary concerns of The Ohio Academy of Science are to encourage and give due recognition to scientific research. Even if parts of our annual program are devoted to the aims and objectives of the particular sciences or all of them these considerations are gone about in ways which must stand the tests of rigorous scientific method. Indeed, this is now being done conspicuously by our youngest member, Chemistry. Our leaders in this section have carefully planned another feature of our program for tomorrow. This is nothing less than the Symposium on Chemistry in Biology. It is our hope that each of you will arrange to be present for at least a part of this well planned effort to give unity to the excellent investigations of some of our sciences. Some of our older sections may do well to see to it that this youngest does not leave us embarrassingly behind in the definition of aims, objectives, purposes and in unifying emphasis.

Some years ago the committee of the legislature of one of our western states was assembled to consider appropriation bills. One of these called for $25,000.00 for research by various departments of the state university. Following the reading of the bill one of the committee members asked, "What the hell is research?" No one knew. A motion to lay the bill on the table was immediately made. Is it merely wishful thinking if we assert that such a lack of understanding and what seems to us indefensible action would not so readily be found today in Ohio or elsewhere in the United States? If not, then is it not due to our having shown at least our political representatives that our sciences in content and method are worthy of careful consideration

and support because for one thing as we become more scientific we become more humane? In the world of machines. strange as it may appear, recent changes in their construction and use reveal that man is increasingly being left in.

Leaving more general consideration aside shall we then consider some of the definite steps to be taken by our sciences to develop in such a way that man himself, his welfare and happiness will not have been left out of what most of us fondly hope will prove to be one of the major achievements of modern civilization.

The successful selection of the young women and men, who by later labors prove that they have the scientific aptitude and other traits necessary for genuine achievement may well be one of our first tasks. Can't this be done, you ask, by the unaided judgment of the mature teachers, directors and investigators through their knowledge of the scholarship and physical and mental traits of their students and other available candidates? The answer we should like to make is "Yes." The real facts answer "No" with some emphasis.

We shall report briefly from a study made some years ago at Leland Stanford University. Zyve inspired and directed by Terman proceeded to construct a test for scientific aptitude. Many leading scientists of the past and present and also their achievements were studied in order to analyze the desirable if not essential elements. We quote: "1. *Clarity of definition*, the ability of the student to differentiate better definitions from poorer ones and appreciate their relative values. 2. *Experimental bent*, the tendency of the student toward experimentation. 3. *Suspended vs snap judgment*, the tendency of the student to draw final conclusions from insufficient data. 4. *Discrimination of values* in selecting and arranging experimental data. 5. *Detection of fallacies* and contradictions. 6. *Reasoning*, the ability to reason not only according to well-established rules such as may be found in certain typical mathematical problems but, also so far as possible, original reasoning. 7. *Accuracy of systematic observations*, the ability to observe, patiently and accurately by adopting some method of systematization. 8. The ability of the student to use given experimental data and form correct inductions, deductions and generalizations. 9. *Accuracy of understanding and of interpretation*, the ability to grasp the true meaning of a given body of information and to interpret it correctly. 10. *Caution*, the tendency of the student to investigate before adopting a method of behavior."

The one word expressing the most significant characteristic of these ten elements is—*Method*. Karl Pearson, certainly one of the leading English Scientists, has observed that those of his students who had achieved most in later life had been outstanding as students by their interest in, and mastery of, method.

Zyve's test built on the above outlined ten elements given to fifty research students in physics, chemistry and electrical engineering so agreed with the ratings by competent judges that the test enabled the author to predict success or failure in approximately three-fourths of the cases. This first attempt to construct such a test was more successful in selecting students with scientific aptitude than are the best intelligence tests in most cases, even after fifteen years of experimenta-

done largely on the basis of the expressed wish of the applicant. There was a high percentage of failure. Later when he cooperated with the Institute staff the percentage of success was as high as failure had been before. In actual application our sciences will hardly leave man in without subjecting his ill-founded wishes even about the work by which he earns his living to most careful but considerate scrutiny.

An English investigator, Earle, not long ago wrote a book on "Choosing a Career." It is in the main an account of a carefully controlled study of what happens to boys and girls if they follow or do not follow the counsel given after thoro examinations of various abilities and traits have been made. Followed up after a few years those who acted on the counsel given are earning more money and what is more to the point perhaps, they are more permanently employed, more contented and happy. They and their employers agree on the advantage of acting upon counsel determined upon after tested methods have been applied.

Some four years ago our own President Bryan suggested that a major problem for study in at least one university might well be that of student dependability or reliability. For example, suppose a student on probation emphatically gave his word that he would meet the standards required if given another chance. What reliable and valid data could be obtained beforehand which would furnish those who have to decide in such difficult and, to the student at least, tragic cases? Well, we've made only a start. But from the very start we must look to the reliability of our mesaures. Merely physical instruments and materials must measure up to a high standard of reliability. A friend of mine in the engraving business invented an apparatus and method for testing the ink sold to him before he would undertake to use it in his finest engraving. Interestingly enough he did this at that time when we found that we could no longer depend on Germany for our chemicals.

It is clear that when we attempt to apply such tests as that of hearing loss, strength of grip, blood pressure, intelligence, mechanical ability, knowledge and mental power we are face to face with this problem of the reliability of our measures. Will the scientific material, apparatus or method used perform a second time and succeeding times as it did the first? Another requirement yet even more exacting is that our methods measure what they purport to measure. Let us illustrate both of these from some recent studies which we have reported as a part of the earlier programs of our own Academy. Some years ago our laboratory purchased at considerable cost an audiometer developed to test the hearing sensitivity of as many as forty children or adults at one time. Some four thousand children have been tested with this equipment; many of these in groups have been tested twice, a week or so apart; some have had even a third test. We can discover those with markedly defective hearing. Even if they are mentally bright and have progressed as far as high school they may not be aware of this defect. This hearing test equipment as a final test does serve us well to demonstrate to a devoted mother that her little daughter is very deaf indeed. It is therefore in this individual case a valid and

reliable test. But when we use it according to directions on groups of twenty to forty from ages seven to adult, make the statistical computations and make comparisons with statistically determined standards, apparently the set-up falls short of satisfying the reliability standards. It follows therefore that it would be wanting in validity as well. My present belief is that its failure to measure up to the rigorous scientific standards imposed is largely due to the variable factors introduced by changes in the subjects between the first and following tests as well as those variables brought in by testing many persons in the same room at the same time. Our sciences cannot worthily leave man in unless these variables are known and reckoned with or, remaining unknown, are recognized as further problems for research. Until we do have them reasonably well solved we stand to do man a disservice by making definite pronouncements by way of diagnosis and treatment.

The next and final main consideration of this discussion is: How shall we envisage the present and future labors of our sciences with man left in so as to get the largest and sanest social values? The members of each of our groups in the Academy, indeed of any science, believe profoundly in the social implications of their chosen fields of endeavor. As evidence of this there can be cited what many of you must have observed often during these five and more years of depression. Scientists have carried on as scarcely any other groups have done. In fact one might argue that in the face of reduced income and facilities many have found added satisfaction in increased labor and zeal. If they had to get along without able assistants they worked all the harder to train younger and less able workers. You will approve I feel if I report to you an observation from my experience as editor of the Journal of Applied Psychology. We have many contributors willing to pay an additional cost in order to have their articles published earlier than the one year approximately which the manuscript would have to be delayed if it took its regular turn.

All this and more signifies that there are manifold and richer meanings involved in sciences so conceived as to include man and his social gains or losses.

Dr. Brewer of Harvard University in 1928 published in the Personnel Journal a study of 4375 cases of discharges from industrial establishments. He classified the reasons for these separations under two main headings: Lack of skill or technical knowledge, and lack of social understanding. By skill the actual doing of the work was meant and by the technical knowledge the *science* back of the work—the *how*. "Social understanding" means human relationship-wisdom, those qualities of character which ordinarily go deeper than skill or technical knowledge.

While incompetence was the largest single cause all those causes which could be classified as skill constituted only a little more than one-third of the total—4375. In about five-eighths of the cases the social understanding causes were the determining factors. It should be kept in mind that no attempt was made to go back of the records kept by these companies the data from which was compiled by the Bureau of Vocational Guidance of Harvard University. Since 1929

another study has been made of a similarly large number of separations from employment in New England industries. Here too the combined effect of lack of skill or technical knowledge—incompetence, slow work, physical inadaptability and spoiling of work was only about one-half as often a determining factor in discharge as was lack of social understanding, that is, insubordination, unreliability, absenteeism, laziness, trouble making, drinking, violation of rules.

The relative influence of the technical versus the social organization of the workers in an industrial plant is brought out clearly in an investigation by Roesthlisberger and Dickson under the direction of the Graduate School of Business Administration and the George F. Baker Foundation of Harvard University.

Studies of small working groups were made at the Hawthorne plant of the Western Electric Company. Workers on the same level were found to exercise strong influence on each other. One may be the socially recognized leader of the group; another a social outcast because of lack of strict conformity with the group customs. It is shown that this social organization often defeats any wage incentive planned by the administration. Even in group piece work in which expert production by one individual would increase the pay envelopes of his co-workers the members of the group very often apply pressure to keep him from exceeding a limit arbitrarily set by themselves. Since the worker cannot himself initiate changes and finds it difficult to adapt to innovations, he blindly struggles to maintain the status quo. The success of management is found to be in its ability to introduce more efficient methods without disrupting the social foundations. This brief report has been taken quite literally from the Psychological Abstracts for April, 1935.

Almost instantly one asks himself if this finds its counterpart in our universities. Dr. Lehman of our Ohio University faculty has anticipated our question by his study of the motivating effect on grades of being pledged to a fraternity, the outstanding social group on the campus. Comparing grades for ten semesters, holding ability and other factors constant, he states that the chances are more than a 1,000,000 to 1 that the grades of the fraternity group *will go down* after the pledges have been initiated into the fraternity. The chances that a group of non-fraternity students' grades will *go higher* in succeeding and comparable semesters are 26 to 1. Motivation is of fundamental significance in all animal and human endeavor. It is being investigated today as never before. Dr. Lehman's study appeared in the February, 1935, issue of The Journal of Applied Psychology. A long list of comparable studies serves to throw into bold relief the unquestionable fact that our scientific achievements and their applications are conditioned and have their being in the social springs of action and behavior. Our sciences leave man and his social behavior out almost at their peril.

Closely related to the suggestive findings just mentioned are the conclusions of the studies of accidents by street railways, motor men, taxicab and truck drivers. We must give considerable weight to studies made by insurance companies in the effort to learn the causes of costly accidents. Their purpose is admittedly a money-saving one.

They employ scientists because they are convinced it pays them to do so. The leading cause of accidents in Cleveland was found to be that of mental attitude, so with a number of other companies employing scientists to make their investigations for them. One of the most significant outcomes of such studies is that with time, accurately gathered scientific knowledge and thorough planning a worker who is a liability can be changed into a valuable asset for the company and himself.

As an aid in understanding in part how our sciences are frustrated we feel constrained to cite Hoopingarner's statement: "Industry in general has been conducted on a conflict basis. Little or no mutuality of interest between capital and labor has been recognized." In each of our sciences and preeminently in those dealing directly with our bodies, our minds and human society we hear all too frequent criticisms racketeering in science. What is the preventive or cure? The rapid but sane development of the positive, constructive, cooperative social factors of each of our sciences. If ever we thought and worked in terms of the conflict basis as did industry and business then let us substitute for it the far more sensible mutual, integrative one.

Our sciences have more difficult tasks than have other disciplines and studies. The extent to which more hours have to be spent in the laboratory leaves less time and energy for the cultivation of the social graces, social judgments and decisions and the art of leadership. Common opinion and careful investigation both support the belief that students of the sciences face a more difficult task than do those majoring in other branches of knowledge.

Almost every member of our Ohio Academy of Science must have raised the question at least in his own mind as to the social and political implications of his teaching and original studies. Even if he has not, the new book called The Frustration of Science will be of keen interest. Concerning this treatise I quote the publisher's own words: "Departing from the academic seclusion which has hitherto restrained scientific men, particularly in America, from entering the field of political controversy, a group of British scientists hurl a bitter indictment at our present industrial and political leaders in a book called The Frustration of Science in which they charge that in every branch, the *destructive* powers of science are being fully exploited by those who now dominate the world, while the enormous constructive benefits which science has made available to society are neglected or deliberately suppressed." This is an overstatement, you say at once. It may well be. However, does not one of the reasons for such a protest by English Scientists rest in the unconcern for human social consequences shown by those who would apply the final fruition of scientific labor?

By no means would I have you understand that anything I have said or implied is to lead to a belittling of the relative worth of the individual person in our scheme of things. With Professor Carlton of the Case School of Applied Science there are many who are pointing out that modern industrial life is dominated by a machine technology; that each of us as consumer can hardly refuse to accept a standardized product at a standardized price; that even science reveals hard facts in nature (even human nature) in all their brutal realism; and that even the very increase in population tends to belittle the individual

person. Is there a way out of all this to be used by our sciences if they are to succeed in leaving man in? Is it too presumptuous to suggest that one way is to scientifically establish the facts of man's social life precisely as we establish the meaning of non-social facts? In each must we not resort to the same controlled and experimental methods? Each few days I pass by a room in one of our university buildings used by one of my colleagues in the Department of History. On the door of this room is a sign which reads "Laboratory Method in the Study of History." Our sciences can justly take much satisfaction in this gradual but certain influence in the adoption of their scientific method in the study of subject after subject earlier regarded as exclusively non-scientific.

"What prevents Social Progress?" by Professor Dwight Sanderson in the April Scientific Monthly gives us from one approach the answer to the question we have raised. Physical inventions have given us our radios, automobiles and aeroplanes. Social inventions which will insure a larger degree of social welfare and happiness depend just as fully on scientific research. The factors of that with which social inventions have to do are human beings and scientifically determined facts about them.

If time permitted citation after citation could be made to prove that our sciences are being called upon to assist business, industry, and government, to discover those who unquestionably possess the art of leadership. What specifically do such persons have to possess either by nature or by nurture? According to one of the best authorities, sense of purpose and direction, integrity, technical mastery, intelligence and faith. I challenge you to show me a group of individuals who exhibit in fact more of these traits than do individuals chosen from our sciences. You will have already observed that I have selected some of the qualities of Ordway Tead's classification of the necessary traits of successful leaders. It would be almost a miracle if our sciences called upon to select successful leaders for other disciplines should not ask themselves if their own leaders could not be selected and trained by the same scientifically controlled methods which they have been looked to for direction and inspiration from others.

As so-called scientists at least we can rather heartily subscribe to the spirit if not to the letter of the graduate of one of our Ohio institutions of higher learning as he writes, "I don't know what it is, nor how it's done, but in some mysterious fashion the students are given a human interest, a wide social outlook, and a growing philosophy of life. Most interesting of all they seem to have acquired an uncanny knowledge of the possibilities of this life." In substance, most members of our Academy would approve most heartily that if those whom we select and train are to finally find themselves as real men and women left really within the sane confines of our sciences we would do well to devote our best endeavors to their social training.

But have we positive, constructive evidence in real lessons from the sciences that we can use as proof that our sciences merit true confidence and faith, that they can produce leaders who are original, inspiring, sane and worthy? The free association method supplies

spontaneously so many examples. So quickly as to be really surprising, Agassiz, Shaler, James, Gordon, Millikan, Cattell, Thorndike, Angell, Miller, Morgan, Einstein, Fischer, Pupin, Haldane, Osborn, Langmuir, Richards, Bosch, Helmholtz, Darwin, Urey, Welch, DeVries, McDougall and numerous others. They and their achievements are the solid basis for the abiding faith to be found in the minds of scientists and science which compares so favorably with these same things in other groups. Having achieved so much without consciously leaving man in, we may within reason look forward to greater achievement when we with purposive intent go about our labors to leave him in.

Toward the close of a long and really successful life one of our scientists writes, "I am desirous of participating in the solution of one more problem in applied psychology. That is the problem of human happiness. Whether or not it fits in with one's philosophy of life, the fact is incontestable that happiness is an important if not the most important aim of human endeavor." These are the words of Dr. Raymond Dodge, the man who by his originality and mastery of scientific method gave to the United States Navy soon after we entered the World War such clever and ingenious inventions that highly skilled navy technicians were scarcely able to understand how such things were possible. Following Dr. Dodge's leadership we now have suggested at least that essentially human happiness for most persons is found in friends, work, nature, success in and enjoyment of work, good health in childhood, success in dealing with persons, and in love of nature. Are not these for the most part precisely those problems either directly or indirectly with which our sciences are preoccupied if they have been moved by impulses which left man and his real welfare in?

In closing then shall we resolve that the sciences in our own Academy shall do all they can to leave man in by—

1. The use of the best known methods to attract to, and select for, our groups those who have either by nature, by training, or both, the highly desirable if not necessary scientific aptitudes for carrying on successfully in their appointed fields of learning.

2. The devotion of our best and tireless energies to making our examinations reliable and valid so that they merit first our own respect, and following that, the respect of our students.

3. The development by scientifically recognized methods highly reliable apparatus and conditions of experiment free from exclusively commercial motives in order that our measurements, diagnoses and treatment may be freer from error and suspicion. Shall we place true values on reliability of performance, by persons, by apparatus, by methods, by well nigh everything?

4. Shall we recognize more fully and genuinely the many complex social problems involved in our sciences to the end that the nature and rights of the individual scientist, student of science and every citizen whose life is touched by science, are sensed, conserved and fostered?

A most fitting close to our discussion can well be in the words of one of my most respected and inspiring teachers, Dr. W. H. Burnham: "The highest form of the learning attitude is the scientific attitude and the scientific method is the great means of developing this attitude."

THE EFFECTS OF PROLONGED INCREASED IODINE FEEDING[1]

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The effects of adding supplemental iodine to the diet of man and of animals has long been a matter of controversy. As a result its advisability has been questioned. Consequently we welcomed a recent opportunity to investigate this problem.[2]

A valuable herd of high milk-producing Brown Swiss dairy cows in New York State had been fed a relatively high iodine supplement for a period of approximately three years. Extra iodine had been given as potassium iodide, in fish meal and in kelp, and as forage crops grown on soil fertilized by iodine-containing substances. Since in the past a number of studies on the effects of iodine feeding have been conducted upon an empirical basis, it seemed of importance to us actually to determine the amount of iodine consumed daily, also the daily excretion of iodine in the urine, feces and milk. In addition the blood iodine was determined.

One of us, (O. E.), has directed the feeding of several large herds of dairy cows in the states of Ohio, New York and Pennsylvania for the past twenty years. Following the work of von Fellenberg, iodine was added to the diets about 1915. These early iodine feeding experiments were of necessity carried on empirically. Adequate micromethods were not available. Since that time suitable methods for determining the iodine content of the blood, milk, ingesta and excreta have been developed (25). These are now being applied.

A preliminary report of the results of this investigation has already been made (28).

HISTORICAL

The basic facts concerning iodine in nutrition have recently been reviewed in a valuable monograph by Orr and Leitch (1).

Subsequent to the historic French experiment (1), Rilliet

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[2]This investigation was made possible by a grant from Mr. William Wallace Kincaid, Ellerslie-on-Niagara, Youngstown, New York.

described toxic symptoms which follow overdosage with iodine. He even denounced the procedure before the French Academy of Medicine. His arguments are still quoted by those hostile to supplementary iodine feeding. However, even before 1860 there were sporadic objectors. In this day of better scientific appreciation and understanding of the importance of minerals in the processes of life there are still those who censure adding iodine to the diet. The significance of minerals in nutrition has been effectively discussed recently by Sheldon (4).

As early as 1831 Boussingault collected data from the goitrous regions of the Andes which pointed to a close relationship between iodine and thyroid disease (1). Thirty-nine years after the discovery of elemental iodine by Courtois, Chatin began his extensive studies on the existence of iodine in nature (2). While his work was recognized, its importance was not fully appreciated at the time. In fact, contemporary chemists were unable to duplicate his findings. Modern advances in microchemistry have enabled scientists and clinicians, as well as chemists, to confirm the observations of these pioneers (3). The original deductions concerning the significance of iodine in biology and in pathology are now better understood, and more knowledge is being added (3, 4).

After preceding failures Baumann (5) succeeded in demonstrating the presence of a considerable quantity of iodine in the thyroid gland. This was in 1895. The thyroid hormone, *thyroxine*, was subsequently isolated, analyzed and synthesized (6, 7). Assay shows it to contain 65 per cent iodine. Recent investigations have further established the relation of iodine to goiter in man (8). The significance of adequate iodine in nutrition as a preventive to goiter is appreciated (4, 9). Adding iodine to the diet of pregnant women is recognized as a significant precaution (10, 11, 12). It would thus appear to be established that to function normally the thyroid gland should have an adequate supply of iodine.

Thus the ground that was lost from 1860 to 1895 has been rapidly regained. Progress in the understanding of iodine metabolism has greatly accelerated during the past decade. With further perfection of the microchemical methods now in use and with their application to determine the minute amounts of iodine occurring in nature, significant developments are certain to ensue.

LITERATURE

Lombroso (13) suggested that in districts where cretinism was common iodine should be added to the diets of animals as well as to those of goitrous individuals.

Several European workers have noted that increasing the iodine in the diet of dairy cows and of goats has increased the iodine content of the milk from these animals (14, 15, 16, 17, 18, 19). Karns in this country has made a similar observation (20). None of these investigators has mentioned any deleterious effects resulting from augmenting the iodine in the diet of their experimental animals. The quantitative studies reported have been done on laboratory animals or upon isolated animals. In no instance has a large number of animals been studied on the more scientific basis. Extensive work has been done on milking goats.

Scharrer found that larger quantities of iodine in the diet of goats increased the milk yield (17). Stiner reports specific instances of having increased the milk yield from 8 to 10 per cent by administering suitable amounts of iodine to cows in recognized iodine deficient areas (21). Hanzlik (22) observed that rats having a diet rich in iodine maintained a better general condition than those not having such a diet. In some of the animals there was an increase in weight and growth. This increase was variable. In his study he also used sulphocyanate, bromide, arsenic, thallium and manganese as controls. These salts brought deleterious results. Arsenic and thallium caused fatalities. Welch and others found that hairlessness in new-born pigs was preventable by giving the pregnant sow food to which appropriate quantities of iodine had been added (23, 24).

METHODS

The quantitative method which we have used for determining the iodine (25) is here summarized. It is the result of adapting modern technic, apparatus and procedures to the principles as developed by von Fellenberg (3). It is carried out in from five to six hours. In careful and experienced hands it is about as accurate and dependable as the micromethod for the determination of the non-protein nitrogen of the blood.

The material to be analyzed is measured or weighed into a nickel crucible and mixed with an adequate amount of potassium hydroxide. This base binds the iodine and facilitates

hydrolysis of the organic matter. After ashing completely the content of the crucible, at a carefully controlled optimum temperature, the water soluble salts are extracted. This extract is evaporated to dryness. The soluble salts are then extracted with 95% ethyl alcohol. The alcohol is evaporated. The remaining dry film containing the iodine salts is dissolved in water. The pH is adjusted to about 4. The iodides present are oxidized to iodates with chlorine water. The excess chlorine is boiled off. A crystal of potassium iodide is then added and the quantitatively liberated elemental iodine is titrated with one thousandth (0.001) normal sodium thiosulphate using starch as an indicator. An especially constructed microburet is recommended for this titration (26).

The food intake was measured by experienced attendants. Since the cows were allowed to drink water at will, from the regular stable fountains, it was impossible to make more than an estimate of the water intake.

Aliquot parts of representative food samples were analyzed. All analyses were made upon the wet basis. The milk, urine, and feces were collected over a period of 24 hours. Attendants were stationed with the cows for the entire 24-hour period. They collected and measured accurately the separate amounts from each cow. Blood was drawn in the usual manner at the end of the 24-hour period.

It is only in unusually efficient dairies that complete records of the milk and butter fat production are routinely kept over a long period of time. For this particular herd a nearly complete record for the years 1932 and 1933 was available.

The clinical condition of the herd was frequently inspected. Evaluation of the clinical results was based upon objective findings. The criteria considered in judging the effects of the prolonged increased iodine feeding were: (1) milk production; (2) general health of the herd; (3) fertility of the cows; and (4) the condition of the calves.

RESULTS

The results obtained are best presented in tabular form.

The iodine content of the foods ingested by the cows, over a continuous 24-hour period, is presented in Table 1. The "grain-mix," to which potassium iodide was added directly, obviously reveals the highest iodine content. The variation of intake, Table 5, is wide. This is due to the fact that the high

milk-producing cows were fed greater amounts of the more concentrated foods. The iodine ingested in the water and roughage is minimal in comparison. The iodine obtained from foraging, from salt, and from other uncontrollable sources is indeterminate. The actual iodine ingested when the cows were also foraging is doubtless in excess of that shown in the table

TABLE I

IODINE INGESTED

Source	Iodine Mg %	Kg. Fed Daily	Mg. Iodine Fed Daily
"Grain Mix"	2 006	2 721 to 9 071	54.59 to 181 98
Alfalfa Hay	0.0326	11 339	3 70
Carrots	0 0099	9 072	0 90
Steamed Feed	0 0508	9 072	4.91
Ensilage	0.0391	10.886	4 26
Water	0 00071	45 359	0 33

Total intake ranged from 68.7 to 196.1 mg. daily

Table II presents a summary of the iodine eliminated in the milk, urine and feces. These figures present the variation of the actual amount of iodine eliminated. The loss closely parallels the intake for each individual cow, Table V. Since the intake is variable a general average has no particular significance.

TABLE II

IODINE EXCRETED

Origin	Output	Iodine Mcgm. %	Mg. Iodine
Urine	10.1 to 18 6 L	269 to 1005	34 6 to 130 0
Feces	9 1 to 29 5 Kg.	140 to 468	15 2 to 71.5
Milk	7 7 to 27 5 L.	15 7 to 181 9	1.5 to 19.5

Total iodine output ranged from 51.7 to 163.4 Mg. daily.

Table III presents a summary of the daily milk production of these cows. Of the 17 cows on which data are available, 13 showed an increase in daily milk production for the year. The average increase was 9.1 pounds. Four of the cows showed a decrease during this period. One of these, No. 59, had been milked constantly over a period of one year and three months subsequent to calving. This cow had an average daily milk production for the month, eleven pounds lower than it was the year before. The other three showed a smaller decrease for the period. The average for the four cows is 7.3 pounds.

TABLE III

COMPARATIVE DAILY MILK PRODUCTION RECORD

Herd No.	November, 1932 Lbs. Milk	November, 1933 Lbs. Milk	Lbs. Gain	Lbs Loss
32	43.6	53.7	10.1	
1	29.6	20.1		9.5
8	19.7	29.9	10.2	
14	24.7	38.4	13.7	
13	20.5	48.2	27.7	
52	32.9	43.8	10.9	
59	40.8	29.8*		11.0
24	20.2	20.7	0.5	
35	18.1	19.7	1.6	
19	17.6	28.1	10.5	
49	37.9	22.7		4.3
54	40.2	35.9		4.3
56	20.1	24.4	4.3	
2	22.3	23.0	0.3	
10	25.4	25.9	0.5	
50	24.9	29.5	4.6	

Average Increase in Production in 13 Cows, 9.1 lbs.
Average Decrease in Production in 4 Cows, 7.3 lbs.

*1 yr., 3 mo. after calving.

Cow 15 made the most outstanding improvement in milk production under this feeding regimen. Data are available on her as far back as 1929. In three years she increased both her milk and butter fat production approximately two and one-half times. Table IV presents this information in summary form from the official G. V. L. record.

Table V presents in summary form the relation between ingested and excreted iodine. The total iodine ingested and eliminated is given in milligrams.

The blood iodine of these animals on a high iodine diet is of particular interest. It is greatly increased. The first modern figure for the iodine content of bovine blood was obtained by Kendall and Richardson (27) as 13 micrograms per cent. In our own studies (25) made on blood from cattle killed at the abbatoir, the iodine content averaged 14 micrograms per cent. The normal human blood iodine is about 12 micrograms per cent (29). This figure has been obtained and confirmed by a large group of workers both in this country and abroad (29).

TABLE IV

COW 15: 8 YEARS OLD

1929

Average Daily Milk Production—25.0 lbs.
Total Milk Produced—9,139 lbs.
Average Percentage Butter Fat – 4.9
Total Butter Fat Produced—447.7 lbs.

*1932**

Average Daily Milk Production—59.9 lbs.
Total Milk Produced—21,924.9 lbs.
Average Percentage Butter Fat—4.73
Total Butter Fat Produced—1,037 1 lbs.

*Official G. V. L. Record.

As shown in Table VI, the range in these twenty cows is from 35.9 to 78.1, averaging 54.9 micrograms per cent. The cows were thus living and reproducing with a blood iodine more than three times its normal level.

DISCUSSION

The value of adding iodine to the diet of dairy cows has been considered by many. Some have tested its effects. Unfortunately in most instances it has been necessary for those who favor the use of supplemental iodine in nutrition to make their experiments sporadically, and to base judgment of their results almost entirely upon objective clinical findings.

The native farmers of Normandy, two centuries ago, procured seaweed to feed their milking cows. They did this because they had discovered a more seemly appearance of the cows after having been fed seaweed. The existence of iodine in seaweed was then unknown. Hence their feeding seaweed was as empirical as the use of burnt sponge in the treatment of goiter. It was not until iodine had been used more or less

TABLE V

Herd No. of Cow	Iodine Ingested							Iodine Excreted			
	Grain Mix	Alfalfa Hay	Carrots	Wet Steamed Feed	Ensilage	Water	Total Iodine Ingested	Milk	Urine	Feces	Total Iodine Eliminated
							Mg				Mg.
8	63 69	3.697	0 898	4 909	4 257	0 304	77 755	3 6	41 5	43 046	88.146
24	63 69	3 697	0 898	4 259	4 257	0 304	77 755	1 9	65 3	28 395	95 595
19	63 69	3 697	0 898	4 909	4 257	0 304	77 755	4 8	103 5	33 090	141 390
18	72 79	3 697	0.898	4 909	4 257	0 304	86 855	3 9	69 2	.	
3	72 79	3 697	0.898	4 909	4 257	0 304	86 855	5 8	55 0	32 297	93 097
13	54 59	3 697	0.898	4 909	4 257	0 304	68 655	3 1	45 5	44 994	93 594
14	63 69	3 697	0 898	4 909	4 257	0 304	77.755	4 9	38 4	53 276	96 576
10	63 69	3 697	0 898	4 909	4 257	0 304	77 755	5 9		23 496	. . .
9	54.59	3 697	0 898	4 909	4 257	0 304	68 655	14 3	51 2		. .
2	54 59	3 697	0 898	4 909	4 257	0 304	68 655	1 5	48 2	15 197	64.897
20	0 0	3 697	0 898	4 909	4 257	0 304	14 065	3.0	26 6	22 112	51 712
1	90 99	3 697	0 898	4 909	4 257	0 304	105 055	6 2	60 7	56 931	123 831
59	109 19	3 697	0 898	4 909	4 257	0 304	123 255	11 3	46 6	66 674	124 574
23	54 59	3.697	0 898	4 909	4 257	0 304	68 655		34 6	54 539	. .
31	81 89	3 697	0 898	4 909	4 257	0 304	95 955	11 7	69 3	44 469	125 469
22	90 99	3 697	0 898	4 909	4 257	0 304	105 055	. .	77 2	35 844	
54	109.10	3.697	0 898	4 909	4 257	0 304	123 255	6 1	85 8	71 483	163 383
35	54 59	3 697	0 898	4 909	4 257	0 304	68 655	10 2	54 2	44 040	108 440
52	90 99	3 697	0 898	4 909	4 257	0 304	105 055	11 2	51 9	59 995	123 095
56	54 59	3 697	0 898	4 909	4 257	0 304	68 655	4 3	43 7	. . . .	. . .
49	90 99	3 697	0.898	4 909	4 257	0 304	105 055	.	130 0	34 638	. . . .
50	109 19	3 697	0 898	4 909	4 257	0 304	123 25	9 9	50 1	50 465	110 465
32	163 78	3 697	0 898	4 909	4 257	0 332	188 873	12 2	74 1	36 143	122 443
15	181 98	3 697	0 898	4 909	4 257	0 332	196 073	19 5	59 3	38 829	117 660

Average Iodine Ingested, 94.17 Mg.

TABLE VI

BLOOD IODINE IN MICROGRAMS PER CENT

Herd No. of Cow		Herd No. of Cow	
8	57.6	1	63.2
24	49.7	59	55.0
18	50.4	31	63.8
3	40.7	54	64.0
13	37.9	35	78.1
14	33.8	56	57.0
10	42.1	50	59.8
9	54.6	32	75.6
2	38.6	15	62.4
20	58.1	38	54.6

The range is from 33.8 to 78.1.
The average is 54.9 micrograms per cent.

extensively in the practice of medicine, and particularly in the treatment of goiter and of cretinism, that it was recommended for animals other than man. One of the earliest records of its use in the diet of animals is in 1859 (13).

Dairymen and veterinarians were slow to recognize the value of iodine as a dietary necessity. In fact many have been skeptical concerning its use, and have even suggested that iodine added to animal diets was likely to cause deleterious effects. The unfortunate experience of giving large amounts of iodine to French school children in 1860 is perhaps responsible for this attitude among those who have not studied the facts carefully.

Twenty years of experience in adding iodine to the food of dairy cows (O. E.) has yielded in no instance objective evidence of unfavorable effects directly or indirectly attributable to the extra iodine ingested. In fact, in those instances where an added iodine food regimen has been instituted, the milk production and the fertility of the cows have increased.

In this investigation, previous to the institution of the increased iodine regimen, still births, goitrous calves, and premature calves were noted. In one of the herds 75% of the cows were sterile or sporadically fertile. In 1933 85% of the cows of this herd were fertile. Some of them were descendants of the original sterile 75%.

Although in this particular study only 25 cows are included a similar increased iodine feeding regimen has been carried out over a period of from three to seventeen years on more than 500 dairy cows of various breeds throughout different localities in the Great Lakes region. In all instances the results have been

distinctly beneficial. In these herds the evaluation of the results has been based upon objective clinical findings.

The general mineral content of the diet of these cows was increased at the same time as that of the iodine content. It is therefore important to state that the subsequent improvement is not necessarily due to the iodine alone. The addition of calcium, phosphorus, iron and magnesium was undoubtedly beneficial to the general health of these animals. However, in other studies carried out by one of us (O. E.) the addition of elements other than iodine did not produce so marked an improvement in the physical condition and reproduction of the cows. It has been observed that the fertility of the cows improved after the addition of iodine to their food. The quality of the calves has improved over that before the institution of the iodine feeding regimen.

This investigation was carried out under definite technical difficulties. No claim is made that it represents a true balance experiment. The travail of making an accurate balance study on patients under strict modern hospital management is beset with difficulties. Hence even to attempt such an approximation upon a herd of dairy cows required courage. The information in Tables I, II, V and VI is as reliable as that given in the average laboratory experiment. The striking increase in the iodine content of the blood and of the milk is significant.

The data which are presented represent a fairly accurate estimate of the increased iodine transport. They show a great increase in the iodine intake. They reveal also a corresponding increase in the elimination of iodine in the urine, feces, and milk. They demonstrate the consequent elevation of the blood iodine. As a whole they reveal clearly increased iodine feeding. Since this had been maintained for a period of three years, and since the clinical condition of the herd was excellent, we were unable to demonstrate any deleterious effects of prolonged increased iodine feeding to these cows.

CONCLUSION

This investigation demonstrates that adding increased amounts of iodine to the diet of dairy cows does not ordinarily produce deleterious effects on the physical condition, general health, milk production and reproduction of these animals. Iodine is apparently beneficial when fed in optimal amounts or, in this instance, even in amounts in excess of the normal requirement.

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ADDITIONS TO THE REVISED CATALOG OF OHIO VASCULAR PLANTS. III[1]

JOHN H SCHAFFNER

The Ohio State Herbarium, at present, contains over 40,000 sheets of vascular plants and in addition to these, collections of considerable size of bryophytes, algae and fungi. During the past year a large amount of material has been received, so large in fact that it has not yet been possible to study it all carefully.

Because of financial assistance furnished by the government through F.E.R.A., four students have been at work, for the allotted time, during three terms, cleaning and anchoring the old specimens and poisoning and mounting the new additions and one extra student has been at work during the spring quarter writing labels for the new specimens, which in itself requires a large amount of time. The herbarium will thus be in much better condition than it has been for a long time.

Complete lists of the species of plants of the Eastern United States, based on the Cambridge International Rules of Nomenclature, are still not available. It is thus considered advisable to continue to use mainly the American Rules until it is possible to make a complete revision, at least of the vascular plants.

Only the rarest and most important species are listed below. Among these are 22 species entirely new to the state catalog. There are also 12 additional Ohio records which have been taken from A. S. Hitchcock's new Manual of the Grasses of the United States and it is hoped that specimens of these will be found from time to time by our enthusiastic collectors. One species has been dropped from the list. The Catalog of Ohio Vascular Plants thus contains 33 more species than at the last report of additions.

During the past year the Department of Botany received a small bequest from Hannah J. Biddlecome, who died in 1934. Miss Biddlecome was one of the earliest amateur botanists of Ohio and in her later years took a special interest in the development of the State Herbarium, presenting her especially fine collections of mosses, liverworts, and ferns, which make a valuable addition to the representation of these groups.

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[1]Papers from the Department of Botany, The Ohio State University, No 363.

HYMENOPHYLLACEAE. Filmy-fern Family

10 2. *Trichomanes boschianum* Sturm. Filmy-fern. Lower end of Spruce Run, and also in Extein Hollow, Laurel Twp., Hocking Co. Chas. R. Goslin.

20. *Anchistea virginica* (L.) Presl Virginia Chain-fern Cranberry Island, Buckeye Lake, Licking Co. Clyde H Jones.

35b. *Dryopteris cristata intermedia.* Edge of swamp. Braceville, Trumbull Co. Almon N. Rood.

53. *Equisetum laevigatum* A. Br. Smooth Scouring-rush. Oberlin, Lorain Co. A. A Wright. Oberlin College Herb

60. *Equisetum silvaticum* L. Wood Horsetail. Oberlin, Lorain Co. F. D. Kelsey. Oberlin College Herb.

67. *Lycopodium complanatum* L. Trailing Club-moss. Camp Wildwood, Big Walnut Creek, Franklin Co. L. E Hicks and E. S. Thomas.

87.1. *Butomus umbellatus* L. Flowering-rush. According to a report by Mr. Louis W. Campbell, this species is spreading rapidly at Little Cedar Point, Lucas Co.

89. *Triglochin palustris* L. Marsh Arrow-grass. Kenard Bog, Salem Twp., Champaign Co. Lawrence E. Hicks.

101.1. *Potamogeton crispus* L. Curly Pondweed. Minerva Park Lake, Franklin Co. F. B. Chapman.

115. *Nelumbo lutea* (Willd.) Pers. American Water-lotus. Loramie Reservoir, McLean Twp., Shelby Co. John H. Schaffner.

150. *Scirpus planifolius* Muhl. Flat-leaf Clubrush. Colerain Twp , Ross Co. Floyd Bartley and Leslie L. Pontius.

160 1. *Eleocharis rostellata* Torr. Beaked Spike-rush. County Line Bog, west of West Liberty, Champaign Co. L. E Hicks. Silver Lake, Bethel Twp., Miami Co. E. S. Thomas.

178. *Cyperus flavescens* L. Yellow Cyperus Seaman Station, Adams Co.; Henley, Scioto Co.; Kincaid Springs, Pike Co. Katie M. Roads. Friendship, Scioto Co. Delzie Demaree.

180. *Cyperus diandrus* Torr. Low Cyperus. Marl Bog on Mrs. Hugh McCoy Farm, Wayne Twp., Fayette Co. Edward S. Thomas and John H. Schaffner.

181. *Kyllinga pumila* Mx. Low Kyllinga. Brush Creek Twp., Highland Co. Katie M. Roads. Cincinnati, Hamilton Co. J. F. James. Columbus, Franklin Co. Wm. C. Werner.

188. *Scleria verticillata* Muhl. Low Nut-rush. Marl bog on Mrs. Hugh McCoy Farm, Wayne Twp., Fayette Co. Edward S. Thomas and John H. Schaffner.

189. *Scleria triglomerata* Mx. Tall Nut-rush. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

191. *Carex sartwellii* Dew. Sartwell's Sedge. Colerain Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.

220. *Carex deweyana* Schw. Dewey's Sedge. "Dry soil, top of rocks." Nelson Ledge, Nelson Twp., Portage Co. Roscoe J. Webb. Received from Almon N. Rood.

265. *Carex plantaginea* Lam. Plantain-leaf Sedge. Liberty Twp., Jackson Co. W. H. Camp. The same Twp., Floyd Bartley and Leslie L. Pontius.

287. *Carex flexuosa* Muhl. Slender-stalked Sedge. Liberty Twp , Jackson Co. Floyd Bartley and Leslie L. Pontius.

288.1. *Carex sprengelii* Dew. (*C. longirostris* Torr.). Long-beaked Sedge. "Dry soil, top of rocks." Nelson Ledge, Nelson Twp., Portage Co. Roscoe J. Webb. Received from Almon N. Rood.

298. *Carex lacustris* Willd. Lake-bank Sedge. Beach City, Sugar Creek Twp., Stark Co. W. H. Camp.

308. *Carex vesicaria* L. Inflated Sedge. Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

325. *Arundinaria tecta* (Walt.) Muhl. Cane. A very large patch in a swamp in southern part of Concord Twp., Highland Co. Katie M. Roads. Near Latham, Mifflin Twp., Pike Co. On moist slope; patch about 10 ft. sq. A. E. Waller.

332 *Bromus inermis* Leyss. Hungarian Brome-grass Accidental on Ohio State University Campus. Columbus, Franklin Co Specimen with the upper spikelets proliferated Clara G Weishaupt.

352. *Panicularia pallida* (Torr.) Ktz Pale Manna-grass. West Swamp, Oberlin, Lorain Co. E S Steele (Contributed by F. O. Grover). Liberty Twp., Jackson Co Floyd Bartley and Leslie L. Pontius

355. *Poa autumnalis* Muhl Flexuous Spear-grass. Berne Twp., Fairfield Co. Wm. Goslin

379.1. *Leptochloa fascicularis* (Lam) Gr Salt-meadow-grass (*Diplachne fascicularis* (Lam) Beauv.) Buckeye Creek, Liberty Twp., Jackson Co. Floyd Bartley and Leslie L Pontius.

382. *Phragmites phragmites* (L.) Karst. Common Reed-grass Cedar Swamp, Champaign Co. Glenn W Blaydes.

384. *Danthonia compressa* Aust. Flattened Wild-oat-grass. Braceville Twp., Trumbull Co. Almon N Rood

385. *Arrhenatherum elatius* (L.) Beauv Oat-grass. Pickaway Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.

390. *Deschampsia caespitosa* (L.) Beauv. Tufted Hair-grass Kenard Bog, Salem Twp., Champaign Co L. E. Hicks.

402. *Agrostis elliottiana* Schultes. Elliott's Bent-grass. Rock Run, Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

416. *Muhlenbergia sobolifera* (Muhl.) Trin. Rock Muhlenbergia. Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

432. *Torresia odorata* (L.) Hitchc. Vanilla-grass. Pleasant Valley, Muskingum Co. Edward S. Thomas.

438. *Lolium multiflorum* Lam. Awned Darnel. Waste ground, Columbus, Franklin Co. John H Schaffner.

464.1. *Panicum anceps* Mx. Beaked Panic-grass. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L Pontius.

472.1. *Panicum tuckermani* Fern. Tuckerman's Panic-grass. Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

474. *Panicum depauperatum* Muhl Starved Panic-grass. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

481. *Panicum bicknellii* Nash. Bicknell's Panic-grass. Liberty Twp , Jackson Co. Leslie L. Pontius and Floyd Bartley.

483.1. *Panicum yadkinense* Ashe. Spotted-sheath Panic-grass. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

488. *Panicum lindheimeri* Nash. Lindheimer's Panic-grass. Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

490. *Panicum tsugetorum* Nash. Hemlock Panic-grass. Sandstone cliff, Toboso, Licking Co. R. B Gordon.

491. *Panicum villosissimum* Nash Villous Panic-grass. Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

492a. *Panicum huachucae fasciculatum* (Torr.) Hubb. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

493. *Panicum meridionale* Ashe. Matting Panic-grass. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

500. *Syntherisma filiforme* (L) Nash. Slender Crab-grass. Adamsville, Muskingum Co. L. E. Hicks and C. A. Dambach.

504. *Echinochloa frumentacea* (Roxb.) Link. Billion-dollar-grass. Glenford, Perry Co. L. E Hicks and C. A. Dambach. Along R R. track. New Vienna, Clinton Co. Katie M. Roads.

534. *Allium tricoccum* Ait. Wild Leek. Buchtel, Athens Co. Len. Stephenson.

568. *Disporum maculatum* (Gr.) Britt. Spotted Disporum. Wooded North hillsides, Camp Gordon, C. C. C. Friendship, Scioto Co. Delzie Demaree.

574. *Unifolium canadense* (Desf.) Greene. False Lily-of-the-Valley. Rock Run, Liberty Twp., Jackson Co.; Sugar Creek Twp., Stark Co. W. H. Camp.

579. *Smilax ecirrhata* (Engelm.) Wats. Upright Smilax. Laurelville, Hocking Co. Muriel Sayre.

589. *Tradescantia pilosa* Lehm. Zigzag Spiderwort. Brown County. Clara G. Weishaupt.

594. *Juncus balticus* Willd. Baltic Rush. Mantua Twp., Portage Co. R. J. Webb and Almon N. Rood.

599.1. *Juncus greenei* Oakes & Tuckerm. from Trumbull Co. Remove from list. According to S. C. Wadmond, of Wisconsin, who is making a special study of Juncus, this is *Juncus gerardi* Lois. (No. 595), a common coastal plain species occurring rarely in the Great Lakes region.

603 *Juncus articulatus* L Jointed Rush Marl bog on Mrs. Hugh McCoy Farm, Wayne Twp., Fayette Co. Edward S Thomas and John H. Schaffner.

611 *Juncoides carolinae* (Walt.) Ktz Hairy Wood-rush. Berne Twp., Fairfield Co. Wm. Goslin.

613. *Juncoides bulbosum* (Wood) Small Bulb-bearing Wood-rush. Near Fort Ancient, Warren Co. Katie M Roads.

617 1 *Narcissus jonquilla* L. Jonquil. Escaped in a thicket, Buchtel, Athens Co. From Europe. Len Stephenson.

622. *Gemmingia chinensis* (L) Ktz. Blackberry-lily. Growing wild in Morgan Co. R. D. Book.

632.1. *Iris verna* L Spring Dwarf Iris. Jefferson Twp., and Union Twp., Scioto Co. A. E. Waller

659. *Ibidium beckii* (Lindl.) MacM. Little Lady's-tresses. Harrison Twp., Vinton Co. Edward S. Thomas.

682. *Ranunculus micranthus* Nutt. Rock Crowfoot Sycamore Twp., Hamilton Co. Anna Roberts Westerville, Franklin Co. W. H. Camp.

745. *Papaver rhoeas* L. Field Poppy. Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

746. *Papaver dubium* L. Corn Poppy. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L Pontius.

765. *Draba verna* L. Vernal Whitlow-grass. Red Hills, Delaware Co. W. H. Camp.

770. *Camelina microcarpa* Andrz Small-fruited False-flax. Near Cedar Swamp, Champaign Co. John H. Schaffner.

788. *Myagrum perfoliatum* L. Myagrum. Columbus, Franklin Co Juliet Coles.

812 *Arabis virginica* (L) Trel. Red Hills, Delaware Co. W. H. Camp Conkles' Hollow, Hocking Co. John H. Schaffner.

825 *Dentaria maxima* Nutt. Large Toothwort. Wellsville, Columbiana Co. Donald F. Wiegel.

853. *Geranium pusillum* L. Small-flowered Crane's-bill. Wayne Twp., Fayette Co. Edward S. Thomas and John H. Schaffner.

885. *Polygala ambigua* Nutt. Loose-spiked Milkwort. Salem Twp., Meigs Co. Clyde H. Jones

916. *Malva sylvestris* L High Mallow. Liberty Twp., Jackson Co. W. H. Camp.

920. *Callirhoe involucrata* (T. & G.) Gr. Poppy-Mallow. Along the railway tracks. Frazeysburg, Muskingum Co. Coll. Inez Baker. From E. S. Thomas.

976.1. *Viola primulifolia* L. Primrose-leaf Violet. In swamp, Buckeye Creek, Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

979. *Viola affinis* Le C. Thinleaf Blue Violet Rich open woods. Otway, Scioto Co. Delzie Demaree.

982. *Viola hirsutula* Brain. Southern Wood Violet. Burton, Geauga Co. Chas. A. Dambach.

1006. *Cerastium viscosum* L. Mouse-ear Chickweed. Liberty Twp , Jackson Co. Floyd Bartley and Leslie L. Pontius.

1035. *Dianthus armeria* L. Deptford Pink. Turkey Creek bottoms, Friendship, Scioto Co. Delzie Demaree.

1060.1. *Chenopodium incanum* (Wats.) Heller. Mealy Goosefoot. From the west. In a vacant lot along the railway. Hillsboro, Highland Co. Katie M. Roads.

1084.1. *Lysimachia producta* (Gr.) Fern. Leafy-bracted Loosestrife. Liberty Twp., Jackson Co. Leslie L. Pontius and Floyd Bartley.

1103. *Pleuropterus zuccarinii* Small. Japanese Knotweed. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.

1125. *Polygonum tenue* Mx. Slender Knotweed. Old Washington, Guernsey Co. Emma E. Laughlin

1139. *Potentilla pumila* Poir. Dwarf Fivefinger. Rock Run, Liberty Twp., Jackson Co. W. H Camp

1162. *Filipendula rubra* (Hill.) Rob. Queen-of-the-prairie. Cantwell Cliff, Hocking Co. Glenn W. Blaydes Kenard Bog, Champaign Co L. E Hicks.

1170.1. *Rosa wichuraiana* Crep Dorothy Perkins Rose. A hybrid var. of the species "Long persistent and spreading from discarded cuttings thrown in a gully." Washington Twp, Highland Co Katie M. Roads.

1178.1. *Rosa lyoni* Pursh Lyon's Rose. Wilson's Fork, Camp Gordon, C. C C., Friendship, Scioto Co. Delzie Demaree.

1204. *Aronia atropurpurea* Britt Purple Chokeberry Brewster Bog, Sugar Creek Twp, Stark Co. W. H Camp

1206.1. *Amelanchier intermedia* Spach. Woolly Juneberry. Cedar Point, Erie Co. Edward S. Thomas. Apparently this species as treated in Britton and Brown.

CALYCANTHACEAE. Strawberry-shrub Family

1229.1. *Calycanthus nanus* (Loisel) Small. Smooth Strawberry-shrub. Native in Salem Twp., Meigs Co. Three miles southwest of village of Salem Center. Clyde H. Jones.

1230. *Acuan illinoensis* (Mx.) Ktz. Illinois Acuan. Two places along a small stream, Washington Twp., Highland Co. Katie M. Roads.

1258. *Lotus corniculatus* L. Bird's-foot Trefoil. Adams Co. D R Dodd

1266. *Phaca neglecta* T. & G Cooper's Milk-vetch. Bank of Grand R., Perry, Lake Co. H. C Beardslee and F. J. Tyler.

1267. *Amorpha fruticosa* L. False Indigo Escaped from cultivation in Cincinnati, Hamilton Co Robert B. Gordon

1278.1. *Meibomia laevigata* (Nutt) Ktz. Smooth Tick-trefoil. Barlow, Washington Co. D R. Dodd.

1313. *Lathyrus tuberosus* L. Tuber-bearing Pea "Growing on right of way. New York Central R. R." Madison, Lake Co. Harry Crofoot. From F J Tyler.

1330.1. *Sedum album* L. White Stonecrop. On ledges of Rocky Fork Creek, Paint Twp., Highland Co. From Europe. Commonly cultivated. Katie M. Roads.

1341. *Chrysosplenium americanum* Schwein. "Neotoma," Goodhope Twp., Hocking Co. Edward S. Thomas.

1350.1. *Daphne mezereum* L. Mezereum. Escaped from cultivation. From Europe. In a swamp. N E of Austinburg, Ashtabula Co. Lawrence E. Hicks.

1417a. *Fagus grandifolia caroliniana* (Loud) Fern. & Redh. Camp Gordon, Friendship, Scioto Co. Delzie Demaree.

1429. *Quercus triloba* Mx. Spanish Oak. Vernon Twp., Scioto Co. Conrad Roth.

1438. *Betula lutea* Mx. f. Yellow Birch. In a narrow bog, Swanton Twp., Lucas Co. Louis W. Campbell.

1439.1. *Betula papyrifera* Marsh. Paper Brich A single tree, evidently native, in a narrow bog in Swanton Twp, Lucas Co. Several trees of *B. lutea* were growing near it. Louis W. Campbell.

1536.1. *Comandra livida* Rich. Northern Bartard Toad-flax Brewster Bog, Sugar Creek Twp., Stark Co. W. H Camp.

1565. *Oxycoccus macrocarpus* (Ait.) Pursh. Large Cranberry. Kenard Bog, Salem Twp., Champaign Co. L. E. Hicks.

1592. *Convolvulus fraterniflorus* Mack. & Bush. Short-stalked Bindweed. "In many localities," Highland Co. Katie M Roads.

1587. *Quamoclit coccinea* (L.) Moench. Small Red Morning-glory. Along the banks of the Ohio River, Scioto Co. Conrad Roth.

1614. *Chionanthus virginica* L. Fringe-tree. Banks of Rocky Fork, Otway, Scioto Co. Delzie Demaree.

1624. *Gentiana crinita* Froel. Fringed Gentian. Marl bog on Mrs. Hugh McCoy Farm, Wayne Twp., Fayette Co. Edward S. Thomas and John H Schaffner.

1672. *Physalis pubescens* L. Low Hairy Ground-cherry. Cuba, Clinton Co. Katie M. Roads.
1750. *Martynia louisiana* Mill. Unicorn-plant A weed in a garden. Kenton, Hardin Co. Harry Grigsby.
1759. *Stomoisia cornuta* (Mx.) Raf. Horned Bladderwort. Kenard Bog, Salem Twp., Champaign Co. L. E. Hicks.
1796.1. *Ajuga reptans* L. Creeping Bugleweed. Along the roadside near Hillsboro, Highland Co. Katie M. Roads.
1816. *Mentha rotundifolia* (L.) Huds. Roundleaf Mint Along the road near Prospect, Washington Twp., Highland Co. Katie M. Roads.
1829.1. *Koellia verticillata* (Mx.) Ktz Torrey's Mountain-mint Kent Run, Muskingum Co L. E Hicks and C. A Dambach. Swampy open bottoms, Blue Creek, Adams Co. Delzie Demaree.
1831. *Koellia pycnanthemoides* (Leav.) Ktz. Southern Mountain-mint. Turkey Creek bottoms, Friendship, Scioto Co. Delzie Demaree
1875.1. *Salvia coccinea* L. Hairy Scarlet Sage. "A very common escape and very persistent" Liberty Twp., Highland Co. Cultivated from the south. Katie M. Roads.
1910. *Aethusa cynapium* L. Fool's-parsley. Near Beach City, Sugar Creek Twp., Stark Co W H. Camp.
1947. *Houstonia lanceolata* (Poir.) Britt Calycose Houstonia. In a wood near Cuba, Clinton Co. Katie M. Roads.
1973. *Viburnum alnifolium* Marsh. Hobblebush. Windham Twp., Portage Co. R. J. Webb, L. S. Hopkins and Almon N Rood.
2001.1. *Diervilla hybrida* Dipp. Cultivated Bush-honeysuckle. "Common escape along road." Hillsboro, Highland Co. Katie M. Roads
2031.1. *Zinnia elegans* Jacq. Zinnia. "Thousands in the edge of a pasture" near Buchanan, Pike Co. Katie M. Roads.
2039a. *Rudbeckia laciniata hortensia* Bail Golden-glow. In a field in N. E. part of Brown Co., edge of pasture lot, N. W. part of Ross Co.; along roadside, S. E. part of Pike Co.; edge of pasture lot, Seaman Station. Adams Co. Katie M. Roads.
2070. *Cosmos bipinnatus* Cav. Cosmos Edge of wood near Buchanan, Pike Co. Katie M. Roads.
2079. *Bidens frondosa* L. Black Beggar-ticks. Lake Loramie, Shelby Co. Edward S. Thomas.
2118. *Chrysopsis mariana* (L.) Ell Maryland Golden-aster. Friendship, Scioto Co. Delzie Demaree. Henly, Scioto Co. Katie M. Roads.
2140. *Solidago riddellii* Frank. Riddell's Goldenrod. Marl bog on Mrs. Hugh McCoy Farm, Wayne Twp., Fayette Co. Edward S. Thomas and John H. Schaffner.
2143. *Bellis perennis* L. European Daisy. Common in a lawn. Athens, Athens Co. M. T. Vermillion.
2211.1. *Achillea ptarmica* L. Sneezewort Yarrow. Adventive in Columbus, Franklin Co. W H. Camp.
2219. *Matricaria matricarioides* (Less.) Port. Rayless Chamomile. Perry Twp., Tuscarawas Co. Irma Nelson. From E. S. Thomas.
2223. *Artemisia ludoviciana* Nutt. Western Mugwort. A very large patch along the road. Farmer's Station, Clinton Co. Katie M. Roads
2236. *Mesadenia reniformis* (Muhl.) Raf. Great Indian-plantain. Ft. Ancient, Warren Co. Edward S. Thomas.
2238. *Mesadenia tuberosa* (Nutt.) Britt. Tuberous Indian-plantain. Pleasant Run Bog, Berne Twp., Fairfield Co. W. H. Camp.
2259. *Centaurea maculosa* Lam Spotted Star-thistle. Salem Twp., Meigs Co. Clyde H. Jones
2267. *Hypochaeris radicata* L Long-rooted Cat's-ear. A weed in lawn. Columbus, Franklin Co. Geo. McClure.
2282.1. *Hieracium floribundum* Wimm. and Grab. Smoothish Hawkweed. From Europe. Warren Twp., Trumbull Co. Almon N. Rood.
2285. *Hieracium greenii* Port. & Britt. Green's Hawkweed. Berne Twp., Fairfield Co. Robert Goslin.
2300. *Lactuca villosa* Jacq. Hairy-veined Blue Lettuce. Highland Co. Clara G. Weishaupt.

2306. *Lactuca sativa L.* Garden Lettuce Liberty Twp., Highland Co. Katie M. Roads.

2307. *Lactuca saligna* L. Willow Lettuce. Buchtel, Athens Co Len. Stephenson. Highland Co. Clara G. Weishaupt.

The following 12 grasses not on the Ohio State List are attributed to Ohio by A. S. Hitchcock in the Manual of Grasses of the United States, published in 1935 by the U. S. Department of Agriculture. These should be added to our catalog and an attempt made by collectors to obtain specimens for the State Herbarium.

329.1. *Bromus mollis* L. Soft Chess.
334.2. *Bromus latiglumis* (Shear) Hitchc. Broad-glumed Brome-grass.
347.1. *Glyceria borealis* (Nash) Batch. (*Panicularia borealis* Nash) Northern Manna-grass.
360.1. *Poa palustris* L. Fowl Blue-grass.
362.1. *Poa wolfii* Scribn. Wolf's Spear-grass
370.1. *Eragrostis poaeoides* Beauv. Low Love-grass.
404.1. *Agrostis tenuis* Sibth Colonial Bent-grass.
419.1. *Muhlenbergia foliosa* (Roem. & Schult) Trin. Leafy Muhlenbergia.
421.1. *Muhlenbergia cuspidata* (Torr) Rydb. Plains Muhlenbergia.
445.1. *Elymus riparius* Wieg. River-bank Wild-rye.
450.1. *Hordeum pusillum* Nutt. Little Barley.
486.1. *Panicum barbulatum* Mx. Barbed Panic-grass.

PHYSIOLOGICAL DOMINANCE AS A FACTOR IN CILIARY COORDINATION IN THE PROTOZOA

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The hypothesis of a localized co-ordination center or "neuromotorium" in the Ciliata has been advanced by Sharp (10), *et seq.* without regard for the work of Verworn (1) and Jennings and Jamieson (2), who have maintained that provided sufficient cilia were present any piece of a ciliate could react as a whole organism. Obviously if such pieces are co-ordinated in themselves there can be no localized center for the animal as a whole.

The question of the behavior of pieces of ciliates has been reopened by Alverdes (3) and Worley (4). Their results would indicate that the more posterior pieces are generally not able to react as the whole organism.

In an effort to clear up part of the situation at least the writer undertook a study of the reactions of pieces of *Spirostomum.* It was found that they are co-ordinated in inverse ratio to their distance from the anterior tip, and that the controlling factor is the amount of anterior material present (this control being especially concentrated in the first few microns of the anterior tip and fading rapidly posteriorly), but that *no definite area* is necessary. The co-ordinating ability therefore lies along the same axis as the metabolic gradient and is present to the same degree as is metabolic activity expressed in that gradient.

Alverdes' results (3) indicate the same condition in *Paramecium*, whereas Worley (4) in the same form suggests a localized "receptor center" on the surface of and anterior to the middle of the animal, in the area asserted by Rees (5) to contain a "neuromotorium." In the latest adjustment however of the Paramecium "neuromotorium" Lund (6) places it internally—aboral to the floor of the gullet and posterior to the position assigned by Rees. In this connection it should be noted that Taylor (7) in his microdissection study of *Euplotes* was not able to find any evidence of function of the alleged "neuromotorium" in that ciliate.

Observations made upon the membranelle series of *Stentor*

roeseli during binary fission by the present writer throw further light upon the question. The first evidence of division is the appearance of the new membranelles in a line down the side of the individual They are totally unco-ordinated. As the new peristomial field develops and begins to project outwardly its membranelles still strike at random, while those of the anterior and older field show a trace of hindrance in their hitherto smoothly co-ordinated action. When the new field has grown to morphological equality with the older and lies in the same plane so that the dividing organism appears to be twinned, *both* membranelle series become co-ordinated and unco-ordinated irregularly, showing obvious lack of control. However, now as the older peristome following the normal course of fission in *Stentor* proceeds to grow on anteriorly from the newer, it *regains its co-ordination*, but the posterior field *relapses into unco-ordination*. This status obtains until division is nearly completed when the anterior daughter is attached to the posterior merely by a thin stalk, (as the animal normally attaches to the substrate), at which time the posterior daughter slowly establishes co-ordination. This becomes complete just before the moment of separation. Bishop (8) has observed that the membranelles of the posterior daughter in the division of *Spirostomum* are unco-ordinated and the writer finds that they remain so for about a second after the completion of division, whereupon they suddenly "snap" into perfect action.

There seems to obtain, then, in the vegetative individual a condition where the more active end maintains ciliary co-ordination, whereas in fission where really two organisms are concerned the second individual is unable to set up its own co-ordination until freed from the domination of the first. There is therefore definitely an *anterior-posterior differential* in behavior in the ciliates discussed and the writer wishes to propose the theory that physiological dominance in the sense used by Child and his school is in some way an important if not the controlling factor in ciliary co-ordination in such forms.

Gray (9) quotes electrical experiments on metazoan ciliated tissue in which ciliary action is inhibited or enhanced by the electric current depending upon its direction of flow. This indicates the influence of dominance and the writer has experiments along that line in progress.

Further analysis of the subjects discussed in this paper will be available for subsequent publication.

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Genetics of Garden Plants

It is of the utmost importance to have available volumes in which the genetics of economic groups is compiled in usable form. Jull has already done this for poultry, and now Crane and Lawrence of the John Innes Horticultural Institution have brought together the material on horticultural plants. The resulting book is an excellent compendium of our knowledge of Mendelian inheritance and chromosomal abberations in a long list of species. An opening chapter on the genetics of diploid plants illustrates the basic principles of heredity, and presents interesting cases of the interactions of genes. This is followed by two chapters on the cytology of diploid plants and polyploid plants, respectively. The genetics of individual species is then taken up. Flowering and ornamental plants, vegetable and salad plants, and fruits, are all considered in detail. An especially fine feature is the series of tables giving the genetic constitution of the various varieties of each species. Bud sports and other variations comprise one chapter, and incompatibility and sterility are each given a chapter. The book closes with an informative section on the origin and development of new and improved forms. A glossary, a bibliography and an index complete the volume. The thanks of all geneticists will be forthcoming to the authors and publishers for making this valuable addition to available genetic information.—L. H S.

The Genetics of Garden Plants, by M. B. Crane and W. J. C. Lawrence. xvi+236 pp. London, Macmillan & Co , 1934.

Amebiasis

This monograph of amebiasis, the first in the field for many years, will definitely strengthen any medical library to which it may find its way. American physicians are notoriously deficient, both in the fundamental aspects and practical handling of protozoan diseases. This volume fills a gap in the contemporary literature of the monograph type relating to this class of disorders, and should be in the possession of every internist.

The various chapters, including etiology, epidemiology and symptomatology, are well balanced in quality and volume of discussion. Especially valuable are the 40 pages in which the parasitic ameba, other than Endamebia histolytica, and the technique of laboratory examinations are discussed. The chapters on pathology are perhaps too prolix and could be easily condensed without loss. One expects a somewhat more complete discussion of the Chicago epidemic, not only because of its importance epidemiologically, but also because of the apparent temporizing measures adopted by local authorities which the author, as a member of the investigating committee, should either condemn or justify to his readers.

Bibliographies. illustrations and indexing, often neglected, are adequate and add greatly to the value of the publication. The constant repetition of 'amebiasis and amebic dysentery' is unworthy of the volume and an unfortunate and unwarranted gesture to the presumed ignorance of the general practitioner.

However, considered in its entirety, the author has made a very worth-while contribution and the volume deserves a wide circulation.—B. K. Wiseman.

Amebiasis and Amebic Dysentery, by Charles F. Craig. 315 pages. Springfield, Ill., Charles C. Thomas, 1934. $5.00.

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FOREWORD

The Symposium on The Nucleus of the Atom and its Structure is the second symposium held by the Ohio State Chapter of the Society of the Sigma Xi, the first one having been on Metabolism. It is the aim of the chapter to present, from time to time as circumstances warrant, a series of lectures on some topic in science where the outposts of knowledge are being rapidly advanced, thus making new scientific material of great importance available to the general scientific reader.

This series on the nucleus is very timely because within the last three years numerous new fundamental entities and concepts have definitely evidenced themselves in nearly all experiments where the nucleus of the atom plays the major role.

The positive electron (or positron) was one of the first of the new entities to be discovered. The positron is similar, except for sign, to the commonly known electron; it was discovered late in 1932 in connection with experimental studies on the origin and nature of cosmic rays. Experiments on cosmic rays have been performed at a multitude of places on the earth, including the stratosphere. Professors W. F. G. Swann, Director of the Bartol Research Foundation and first speaker on this symposium, has with his colleagues contributed much to our present knowledge of cosmic rays.

Deuterium (heavy hydrogen) since its discovery has given to the physical, biological and medical sciences an ever increasingly useful and powerful tool. Many of the experiments performed recently owe their successful results to the larger quantities of deuterium made available by the few heavy water plants now in full operation. Professor H. L. Johnston has developed one of the very best plants in the country and has carried out many original experiments on this new isotope in its various compounds.

Artificial radioactivity, discovered last year by the Joliots, promises to be one of the really big steps in nuclear physics.

Already some 70 new nuclei have been synthesized and identified. A considerable development in the use of these radioactive nuclei as indicators for studying the behavior of their inactive isotopes is anticipated in the near future in the chemical, biological and medical fields. Professor E. O. Lawrence and colleagues at the Radiation Laboratory of the University of California have developed a four million volt cyclotron which has been notably successful in synthesizing a large number of these new nuclei.

Theoretical relations and new general principles are bound to follow in the wake of new discoveries. The beginning and development of the theory of nuclear transmutation processes owes much to Professor G. Gamow's contributions. The role of nuclear physics in astro-physical problems and in the theoretical origination of the chemical elements has also been given serious consideration by Professor Gamow.

The building blocks of matter, as we now know them, may change or be added to from time to time, but already our knowledge is quite extensive, although deficient in many respects. Undoubtedly then, it behooves all scientists to acquaint themselves with the essence of this knowledge so that they themselves may perhaps see an application of the new nuclear discoveries in their own special lines of endeavor.

F. C. Blake,
Chairman, Program Committee.

Editor's Note

Once again the Journal is pleased to be able to publish a series of Sigma Xi lectures on a timely and interesting topic. The prompt publication of these lectures in symposium form is made possible by the financial assistance and the editorial co-operation of the Society of the Sigma Xi.

L. H. S.

NUCLEAR PHENOMENA AND COSMIC RAYS

W. F. G. SWANN
Director, Bartol Research Foundation

THE CHARACTERISTICS OF NUCLEAR ENTITIES

Meaning of the Existence of the Particles:—It is only a few years since physics hoped to correlate all the architecture of matter in terms of the ultimate properties of two entities, the electron and the proton. Now with a suddenness which is almost embarrassing, several other particles have been thrown into the arena and demand consideration in building the structure. Among the particles now available we have:

1. The electron.
2. The proton.
3. The positron.
4. The neutron.
5. The photon.
6. The deuton.
7. The hydrogen particle.
8. The alpha particle.
9. Nuclear entities of various kinds usually regarded as composed in some way of more fundamental entities 1. to 4.

In cosmic-ray matters, at any rate, entities 1 to 5 form the main field of our interest, although the more complicated particles do enter into the discussion.

When we are presented with an array of entities such as those referred to, and raise with ourselves the question as to whether or not certain of them exist in the nucleus of some atom, we are apt to encounter ambiguities of meaning founded upon whether some complicated particle such as an alpha particle exists in the nucleus as an individual entity, or whether it is to be thought of as made up out of such things as protons and electrons. We are confronted, for example, with the question of whether the proton is to be regarded as a neutron plus a positron, or as an entity distinct in itself. In some atomic transmutations we may raise the question as to whether some of the particles which we observe were in the nucleus originally or whether they were formed in the process of its disruption. These uncertainties of meaning become enhanced when we try to picture a structure for the nucleus. In classical theory we became confronted with the problem of putting into a nucleus of certain limited size a number of entities whose classical dimensions were so great that they would have to

overlap in order to accommodate themselves. In wave mechanical theory the various entities appear dissolved in a kind of mathematical fluid, from which any one may be precipitated at any desired moment for inspection by a suitable reagent which takes the form of a mathematical operation. Under such conditions it may not be out of place to pause a moment, from time to time, for the purpose of deciding with ourselves what it is that we are talking about, and in particular as to what meaning is to be attached to the statement that a certain entity, let us say a proton, is, or is not, inside a nucleus; and, if in the nucleus, as to whether it exists there as a fundamental entity or as something which is to be thought of as made up of two entities—for example a neutron and a positron. To my mind, definiteness of statement can only be secured along such lines as the following: When we wish to introduce into our problem such an entity as an atom, that atom has a certain mathematical representative which is responsible for all of its activities in the theory. That representative may be a Hamiltonian function. This function figures in some differential equations which are representative of the theory of the subject. In these differential equations are certain co-ordinates which are potentially representative of all of the entities which may figure in the discussion of all that may occur.[1] Any particular solution of these equations represent a *state* of the system. Some of the co-ordinates representative of certain entities may be absent *in any particular solution.* If such is the case, the entities concerned are absent in the state representative of that solution. It may be possible in the case of some particular solution, representative of a state, to make a transformation of co-ordinates in such a manner as to reduce the number of the co-ordinates. Then, entities characterized by the new co-ordinates may be said to exist in the state concerned.[2] Thus, suppose among the fundamental entities we had neutrons and positrons, but not protons. Then a free proton, or a proton in an electric field, for example, is to be considered as a system which, primarily represented by a function of the co-ordinates of a neutron

[1]The entities are supposed chosen so that they represent the minimum number necessary for telling the story of all that may occur through the agency of the accompanying mathematical theory.

[2]In this manner, for example, the co-ordinates of a suitable number of protons and electrons may, in certain cases, be mathematically welded into the much smaller number of co-ordinates of an alpha particle.

and a position, has been found, through a transformation of co-ordinates, to be represented by new co-ordinates to the extent of half the number. If, now, we raise the question of whether in an atom there are protons, or neutrons and positrons, the question at issue is whether the same transformation which reduced the number of co-ordinates in the single case of neutron and positron, above cited, will now function in similar manner to reduce the number of co-ordinates in the function representative of the state of the atom in question. If it does, we may say, by hypothesis, that a proton exists in the atom. It matters not whether some experiment reveals a proton as apparently ejected from the nucleus. The story of whether the said proton was, or was not, in the nucleus has no meaning except in the light of some definition; and the definition I have suggested seems to be the only obvious one available.

Significance of the Existence of Different Atoms:—While speaking of these rather general philosophical matters, one cannot resist the temptation to speculate a little further upon the significance of the quantum theory. At present we have a separate differential equation for each atom, the atom in question being characterized by the form of a certain function—the Hamiltonian function—entering into the equation. The different states of the atoms are characterized by the different solutions which are to be permitted as acceptable according to a certain criterion—the criterion of finiteness, single-valuedness, etc. May it not be that the different atoms themselves are to be regarded as representative of "quantum states" founded upon a yet wider idea of quantization. Many possibilities suggest themselves. Speaking generally, atoms of successively increasing atomic number are characterized, in part, mathematically, as systems of increasing numbers of co-ordinates. May it not be that there is one fundamental differential equation, or set thereof, involving, perhaps, in the initial instance an infinite number of co-ordinates, but of which only certain of the solutions satisfy the criteria demanded, finiteness, single-valuedness, etc., for example. It may be that all the solutions involving certain specified numbers of co-ordinates would be unacceptable. Presumably those involving more co-ordinates than are found in the heaviest known element would come into this category. The individual solutions in which the number of co-ordinates were limited would naturally satisfy, in addition

to the general differential equation involving the multitude of co-ordinates, certain special differential equations involving only the co-ordinates occurring in the solutions. Presumably these special differential equations would be those which we now think of as characteristic of the individual atoms.

Similarity of Different Particles for High Energy:—Another matter of significance concerns the respect in which the particles 1 to 9 really differ from one another. Of course the electron and positron differ from the neutron and photon in that they possess electric charge, and so have qualitative properties different from those of the uncharged entities. This is, however, only a special aspect of differences in properties such as one may think of as existing between the photon and the neutron, to which I shall presently refer. I wish for the moment to raise the questions involved in these particles in what we may call collision phenomena. The story of collision phenomena is governed, though not completely controlled, by two laws, conservation of energy, and conservation of momentum, which we may symbolize by considering a collision in which all the entities from (1) to (5), for example, are involved, and where, therefore, with subscript e for the electron, p for the positron, n for the neutron, P for the proton, and q for the photon, we may write

$$E_e + E_p + E_n + E_q + E_P = E_e' + E_p' + E_n' + E_q' + E_P'$$

where the dashed and undashed symbols refer to the conditions before and after the collision. Similarly, the conservation of momentum may be symbolized by the equation

$$M_e+M_p+M_n+M_q+M_P = M_e'+M_p'+M_n'+M_q'+M_P'$$

In these equations the various particles are characterized by the fact that, for particles (1) to (4) inclusive,

$$E = m_o c^2\left(\frac{1}{\sqrt{1-\beta^2}}-1\right); \quad M = \frac{mu}{\sqrt{1-\beta^2}}$$

and for the photon,

$$E = h\nu; \qquad M = h\nu/c$$

Here the material particles are characterized by a rest mass m_0 and a velocity u, and the momentum of a particle is not expressible completely in terms of the energy. The quantum momentum is, however, completely expressible in terms of the corresponding energy, and indeed we may allow ν to evaporate

from the picture and simply say that the momentum of the quantum is E/c. It is of interest, however, to extrapolate the situation to velocities comparable with that of light, for which case m_0 is negligible compared to m. Thus, for example, in the case of an electron of a hundred million volts velocity, m_0 forms only half a percent of m; and, for such electrons and positrons as figure in the primary cosmic rays, m_0 forms only one part in twenty thousand, or less, of m. For protons of 10^{10} volts energy, m_0 still amounts to 5% of m, but for 10^{11} volts it forms only 0.5%. I wish to emphasize that at sufficiently high energies we may write for all of the particles, including the photons, M = E/c, and the equation of conservation of energy and momentum are completely summed up in two statements of the form

$$\Sigma E = \text{constant},$$

one vectorial, and the other scalar. All characteristics of the material particles and of the quantum have disappeared with the exception of the energy. A quantum and a proton of the same energy would behave in exactly the same way as regards what conservation of energy and momentum would have to say. Distinctions between the entities must now be sought on lines other than those having to do with conservation of energy and momentum. These distinctions commence to show themselves when we consider *experiments* to verify the predictions of the conservation of energy and momentum laws. Then the energy of the electron becomes something which is measured by a path deviation in a magnetic field, for example. The energy of a photon is something which is measured in a way which may be illustrated by the following example: Photons fall perpendicularly upon a hypothetical crystal grating. We confine our attention to those which come in some definite direction in relation to the grating. This direction defines for us the energy E to be assigned to the photon. You will see that I am thinking of the diffraction patterns produced by the photon; but I wish to suppress this idea in your minds, if you will permit me. I wish you to come upon it in another way. I wish to say that my measurement of the energy of the photon in terms of the angle of which I have spoken is, in the first instance, a matter of arbitrary definition; and, in the expression of the relation, an intermediate quantity $\lambda = hc/E$ comes in, or rather a series of quantities hc/E, 2hc/E, 3hc/E, etc.

They come in abstractly in determining the various angles at which the rays coming off from the grating correspond to the same energy. They are, of course, the wave lengths λ, 2λ, 3λ, etc., which figure in that picture of the phenomenon which regards everything as represented by a train of waves, of wave length λ, and of corresponding frequency $\nu = c/\lambda$, incident upon the crystal. From our standpoint the wave picture is not to be regarded as any real thing, but more as an artificial mathematical substructure analogous to Fourier's analysis, and the frequency ν is born of the primary concept of energy rather than the energy being born of the frequency ν. Relegating frequency to this abstract role relieves us of those apparent difficulties which arise in our minds when we try to picture a quantum simultaneously as a particle and as a wave spreading throughout the universe.

Then again a difference between the kind of particles, quantum, electron, etc., makes its appearance when these particles act as perturbating influences upon some atom, or where their energies are deduced on the basis of some theory of their absorption in matter. In such cases, the electron, for example, becomes introduced as a perturbing agent productive of a field of the kind we may associate with a moving charged particle, whereas the photon is represented as a periodic disturbance. In such fields as these the maximum of distinction prevails between the photons and the charged particles and the neutrons, but it is a distinction inherent in, and depending for its meaning upon, the theory of the processes assumed.

The foregoing remarks have been made not so much with the object of drawing any constructive conclusions from them, as for the purpose of cementing what appears to be the logical attitude towards them in any problem which concerns their nature. One constructive feature, however, following from the condition which all of these particles attain when the energy is sufficiently high, is a feature following from the fact that the energy is in all cases proportional to the momentum. The feature in question involves that in a collision between two particles of the same or of different kinds, one of which is initially at rest, the velocity after collision is in the same direction as that before. Thus, if the particle a collides with particle b, initially at rest, resulting in a supposed change of direction of a, we have, from the momentum condition

$$E_a = E_a' \operatorname{Cos} \theta_a + E_b' \operatorname{Cos} \theta_b ; E_a' \operatorname{Sin} \theta_a + E_b' \operatorname{Sin} \theta_b = 0$$

and from the energy condition

$$E_a = E_a' + E_b'$$

which demand for their consistency that Cos θ_a and Cos θ_b shall both be equal to unity. The feature is a very valuable one because it tells us that in the impact of very high energy cosmic rays with atoms so as to produce secondaries there is a perpetuation of the direction of the primary corpuscle so long as no energy goes into processes other than those involved in the laws of impact as specified.

Cosmic Rays

I must pass over introductory matters relating to the history of cosmic rays, methods of measurements, etc., and must take the matter up at the stage where we have to realize that a radiation of enormous penetrating power is entering our atmosphere. All the various particles which have been cited may be regarded as candidates for the position of cosmic rays. However, their credentials are different. Heavy charged particles such as alpha rays face the difficulty that all theories lead us to expect a very high absorption of such particles in the atmosphere, unless they possess an energy so high that their rest mass is negligible compared with their total mass. When this condition is satisfied, their rate of loss of energy by ionization alone depends only upon their energy and upon the square of the nuclear charge.[3] However, the energy which such a thing as an alpha particle must attain in order that its rest mass shall be as unimportant as that of an electron of the same energy is about 8,000 times the magnitude of that electron's energy. For such reasons alpha particles and heavy nuclei have not featured to any considerable extent as candidates for the position of primary cosmic rays, however great a part they may play in the subsequent activity, initiated in the first instance by the primary rays, and leading to atmospheric conductivity. However, such things as alpha particles, and particularly protons, are considered by more than one investigator as presenting reasonable credentials for consideration as primary cosmic-ray particles.

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[3]I must here utter a word of warning based upon the fact that the crowding of the lines of electric force towards the equatorial plane perpendicular to the motion is a phenomenon depending upon the velocity rather than the energy. This phenomenon plays no ultimate part except when radiation reaction is considered. But, if it should play a part, then, to that extent, high energy particles of the same charge and energy would not be equivalent, regardless of their rest masses.

It is of course to be understood that practically all of the phenomena by which we observe cosmic rays are produced by secondaries. The cloud expansion chamber shows us an ample occurrence of phenomena in which relatively soft rays of only a few million volts velocity make their appearance, from some matter in the vicinity, sometimes in large groups, and obviously as the result of the initiation of some act by the primary rays. Occasionally from a mass of lead, for example, there will spring out bursts of rays, as many as five thousand in number. These rays do not appear to emanate from one point, but from several centers. Dr. G. L. Locher, at our laboratory, has given evidence for supposing that the primary center, where the burst initiates, emits neutrons among other things and that these neutrons serve as secondary initiators of the disruption of other atoms, so that the whole phenomenon spreads through the material, or throughout a portion of it, and so results in the very large bursts which are observed. We are at present conducting experiments along other lines and have a certain amount of evidence to show that bursts in one piece of matter can initiate bursts in others. This evidence is contained in an experiment carried out by Dr. and Mrs. C. G. Montgomery and myself. In this experiment we measured the bursts produced in the walls of an iron sphere which was suspended below a large tank of water so that the amount of water could be varied. It was found that the frequency of the bursts increased with the thickness of the water and then diminished with further increase. The increase of burst-production with increase of water is attributed to the stimulation of bursts in the iron sphere by the bursts produced in the water. The further diminution of bursts with increased thickness of water is attributed to a compensating action resulting from the absorption of the primary radiation by the water. The actual experiments showed an increase of 20% in the frequency of the bursts corresponding to 0.5×10^6 ions, for a water thickness of 79 cms. To remove the possibility that the apparent increase of number of bursts in the sphere represented simply a measurement of spurts of ions produced in the sphere by rays which had come directly from the water, the iron sphere was replaced by a magnesium sphere, and the experiments were repeated. Any effect produced by the direct action of the rays from the water, without intermediary action in the walls of the sphere, should show itself just as well for the magnesium sphere as

for the iron. However, no increase in burst frequency was found by increasing the thickness of the water when the magnesium sphere was used.

The fundamental significance of this experiment is that it substantiates the opinion expressed by Dr. Locher to the effect that a number of atoms participate in the production of the bursts. This gives us some relief from the difficulty inherent in the fact that the total energy required to produce some of these bursts is greater than the energy which could be reasonably expected to be liberated in one act in any atomic process which we know of, including the complete annihilation of heavy atoms. It also weakens considerably the claims of a rival theory which has been put forward to account for the origin of these bursts, and which, in view of its dramatic nature, I must not pass by without mentioning. Recent developments in atomic structure and the theories thereof have come to a realization of the possibility of the disappearance of matter and the accompanying appearance of radiant energy in proportional amount. They have also envisioned the reverse process in which radiant energy can be converted into material substance. The general idea of the production of these bursts inherent in the theory to which I have referred is to the effect that radiant energy in the form of a photon cosmic ray descends upon the substance under test. Occasionally such a ray comes into violent contact with the nucleus of an atom. Under these conditions it is supposed that nothing in particular happens to the atomic nucleus, but that the photon becomes mathematically irritated in such a manner as to cause it to decide to change its existence, commit suicide, and become resurrected as a group of particles. If you should ask for a crude analogy, I suggest that you think of a spiritualistic seance. The photon is the ghost, the shower of particles is the materialized ghost, and the atom is the medium.

There is sometimes even an indication of a delay between the different portions of an atomic burst. Fig. 1 shows a galvanometric trace on moving photographic paper showing a burst at the point marked by the arrow. The burst is recorded as ionization in a closed chamber; but, as a check, a system of counters was distributed about the chamber so as to record these bursts by other means. The sharp lines indicate the discharge of the counters and it is obvious that we have here two discharges separated by a distance of what amounts to about

one second, and which seem closely associated with the complete bursts as recorded by the galvanometer. It is perhaps too early in view of the limited number of such cases to say that we have here an illustration of induced radioactivity brought about by cosmic rays, but the result indicated is at least significant, particularly when it is remembered that, with the arrangement of tubes used the chance of two random discharges coming as close together as these is negligible.

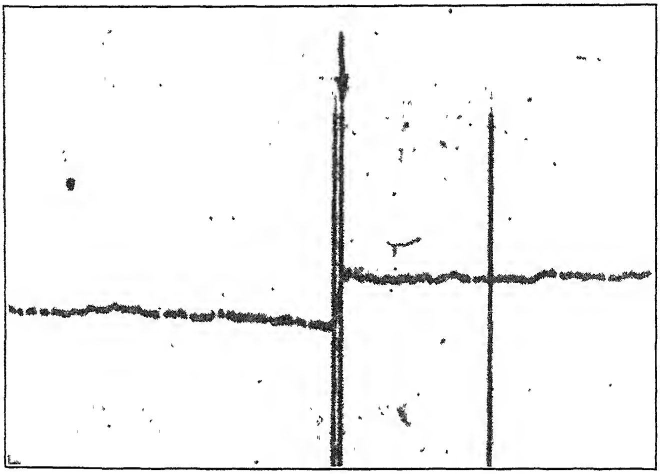
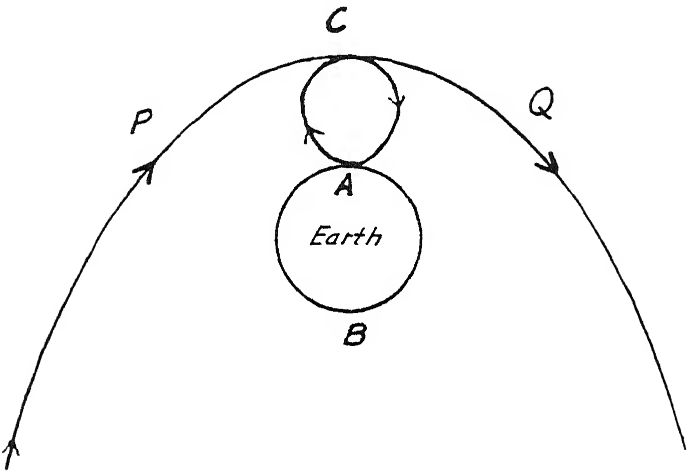


FIGURE 1

The Exponential Law of Absorption:—It has, of course, been known for many years that what is now called the cosmic-ray intensity varies with altitude in a manner which is approximately described by the supposition that the radiation is absorbed according to an exponential law. Now the hypothesis that the primaries are composed of photons of definite frequency lends itself reasonably readily to the explanation of such a law. The characteristic possessed by photons which is of significance in this connection is that of passing through matter without the continual loss of energy in small amounts, the energy losses being confined to amounts comparable with the whole energy of the photon, but taking place only rarely. Under such conditions the intensity of the radiation is governed by the laws of chance in relation to the distance travelled, just as chance determines the density of a stream of bullets at different distances from a machine gun, when the machine gun is fired

into a forest. On the other hand, charged particles, at any rate those of energies comparable with those met in former investigations, lose energy continually in passing through the air, the individual energy losses amounting to insignificant fractions of the total energy of the ray concerned. Under such conditions the rays have a definite range. A parallel beam of rays suffers no change of intensity as measured by the density of the rays until the distance is reached at which its intensity falls to zero. Thus, at first glance, at any rate, the hypothesis of charged corpuscles is entirely unsuited to the explanation of the exponential law of absorption. Until comparatively recently, moreover, the hypothesis of charged particles was ruled out on the basis of the effects which they would imply as the result of the action upon them of the earth's magnetic field.

Evidence of Charged Particle Primaries:—The earth's magnetic field is a very potent agent in controlling the activities of charged particles which seek to approach our earth. The earth's field is weak but its extent is great, so that at the equator an electron must have from one to six times ten thousand million volts energy depending upon the direction in order to reach the equator. The energy necessary for entering becomes less and less as we proceed toward the poles. The orbits of the electrons assume extraordinarily complicated forms. The smaller the energies of the rays, the more easily are the paths bent. Many years ago, the Norwegian physicist, Carl Störmer, suggested that the Aurora Borealis might be caused by electrons emitted in this case with great energy from the sun. The effect of the earth's magnetic field upon these electrons would be to cause them to move toward the polar regions. The smaller the energy, the more would be the bending of the electrons' paths in such manner as to cause them to enter the atmosphere near the poles; and, even to get the aurora to exhibit itself, on such a theory, at latitudes as low as that at which it is found, Störmer found it necessary to attribute to the electron energies a thousand times greater than any which had been encountered in the laboratory at that time. In those days such an assumption was regarded as very speculative. The mathematics of this subject is contained in its essential elements in the work of Störmer, done some twenty years ago. However, the subject has received a renewed interest in the light of modern developments in connection with cosmic rays. It has been convenient to consider certain specific matters



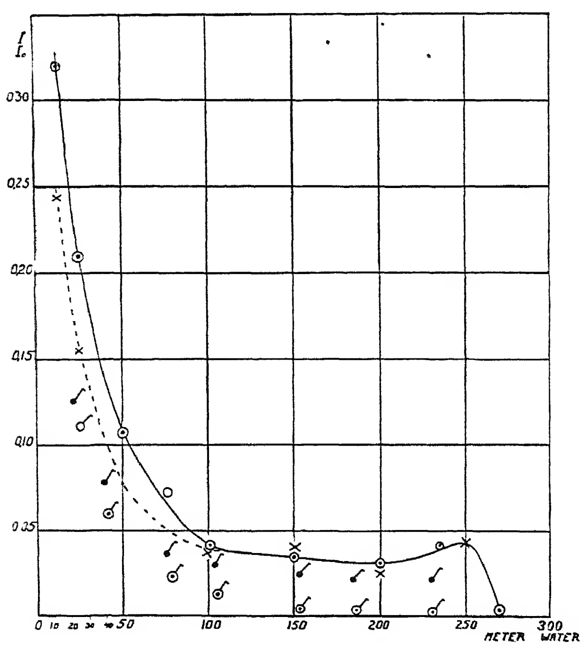


FIGURE 2 (Upper)
FIGURE 3 (Lower)

sometimes as generalizations of, sometimes as special cases of Stormer's theory, and sometimes by special calculations made *ab initio*, with the immediate end in view. Ten years ago, I showed by calculation that an electron with an energy so large that a thousand million volts would be necessary to give it that energy, would not be able to approach the earth in its equatorial plane nearer than to eight times the earth's radius, without being turned back into space. To reach the earth's surface at the equator, an electron must have an energy at least equivalent of that attained under a potential difference of ten thousand million volts. Even under these conditions, as I pointed out about three years ago, the electron which just succeeds in reaching the earth at the point A, Fig. 2, travelling in the magnetic equatorial plane, does so by describing a complete loop. It is easy to see why the electron describes such a loop. You might think that an electron coming from the lower half of the diagram and approaching the earth, would try to reach it at some point such as B. However, as the electron approaches the earth, the earth's magnetic field demands that the path of the electron shall bend, and continue to bend. In order to be able to obey the earth's magnetic field and yet reach the earth, the electron describes the orbit PCAQ shown in Fig. 2. By looping the loop completely, it is able to secure the maximum amount of bending in obedience to the earth's magnetic field, and indeed actually makes use of this bending to come back and touch the surface of the earth before it returns to space.

Now my purpose in showing Fig. 2, is to call to your attention the complicated nature of the orbits of electrons approaching the earth. Störmer spent very many years in calculating these orbits; and, indeed, they can not be calculated by elementary processes of mathematical procedure. Many of them twist about and curve all over the place in most fantastic manner. Under these conditions one might suppose that if an appreciable fraction of the primary cosmic rays was composed of electrons, there would be a very great variation of cosmic-ray intensity with latitude, in view of the fact that it is easier for the electrons to get in at the poles than at the equator. Since until recent times no such variation with latitude was known, it was customary to assume that no appreciable fraction of the primary rays could consist of charged particles. Then three or four years ago, J. Clay in Europe and A. H. Compton and his

associates, in a world survey, found a definite variation with latitude, but of a rather peculiar nature. For latitudes north or south of 34°, there was very little variation. For latitudes lower than 34°, there was a diminution in cosmic-ray intensity which amounted to 14% of the equatorial value at sea level, and to as much as 33% at an altitude of 4,300 meters. Such a condition was at first very difficult to understand. Then it was shown by Lemaitre and Vallarta that if a certain mathematical theorem concerned with the motion of the electrons in the earth's magnetic field could be regarded as true, the story of the cosmic-ray intensity, although extremely complicated in the actual details concerned with the orbits of the electrons themselves, should show remarkable features of simplicity as regards the intensity itself. It turned out that if the theorem to which I have referred was true and if the cosmic rays were uniformly distributed in direction in outer space, then, while their paths would be enormously distorted as they approached the earth, they would be distorted relatively to each other so that the number of rays coming through a cosmic-ray telescope pointed in any direction would have the following characteristics. At any assigned place, and for any one energy of ray, *either* the number would be exactly the same as it would have been had there been no magnetic field, in spite of the fact that the direction of these rays, if produced backwards outside of the earth's atmosphere to remote distances would there have nothing like the directions which they would have had in the absence of the earth's magnetic field, *or* the number would be zero. There could be no compromise. Either the electrons came in with the normal intensity or they did not come in at all. The truth of the mathematical theorem to which I have referred was first sensed by Lemaitre and Vallarta. It was found subsequently to involve principles rather more subtle than had first been supposed, but later by a more rigorous mathematical treatment of the subject I was able to establish the truth of the theorem in a manner which I believe is regarded as satisfactory even by those who have doubts concerning the complete story of the Lemaitre-Vallarta theory itself. The significant elements of the Lemaitre-Vallarta theory may be illustrated in the following way. Suppose that we confine our attention to electrons of any one energy, and, let us say, of positive sign. Then, in general, if we should take our stand at any

particular latitude on the surface of the earth, there would be, for any assigned electron energy, a certain cone with its axis of symmetry tangential to the earth and pointing due west. Within this cone no rays of the assigned energy would enter. Outside of it, the rays would enter with the normal intensity. As we moved towards the pole, the cone would become narrower in angle; and, at some latitude sufficiently high, would become so narrow as to close up completely, so that, at this latitude, there would be no direction from which rays of the assigned energy could not enter, and the same may be said for all higher latitudes. Going back to our starting point, however, and moving towards the equator the cone would widen up in angle so that the direction from which rays could not approach would comprise more and more of the sky. If the assigned energy of the electrons were sufficiently small, the cone would widen up to such an extent as to turn inside out and cover the whole of the sky. Under these conditions no rays of the energy concerned would reach the point in question from any direction whatsoever. On the other hand, if the energy were sufficiently high, the cone of exclusion would narrow down to a small angle, even to zero angle at the equator itself, so that here and everywhere else on the earth, rays of this energy would enter from all directions.

This story of the cone contains the story of the variation of the total cosmic-ray intensity with latitude, and it also contains the story of the difference between the intensity from the east and from the west for any given latitude. If all the rays had one single energy and all carried the same sign of charge, say positive, the story of the difference between the intensity from the east and from the west would be very simple. If we were at a place where the cone of exclusion existed at all, there would be no intensity from the west and the full intensity from the east. In general, this story is complicated by the existence of a wide range of energies for some of which there is an exclusion angle and for some of which there is not. It is also complicated by the possibility of there being charged particles of both signs. It is obvious that if charged particles of both signs existed in equal amounts there would be no difference in intensity from the east and from the west, although there would, of course, be a reduction in each of these intensities. The whole story of these latitude and directional effects is rather complicated, and I must not enter into it in detail. It

must suffice to summarize the main facts.[4] By experiments carried out by T. H. Johnson and J. C. Street on the top of Mount Washington in the summer of 1932, the existence of an east-west asymmetry was verified and the observations were such as to indicate that the charged particles responsible for the effect were charged, preponderatingly, positively. These results were confirmed and extended by the work of T. H. Johnson, and independently by that of L. W. Alverez and A. H. Compton in Mexico. Since that time Johnson has extended the observations to a wide range of altitudes and to equatorial latitudes. Combining the results of the experiments on the latitude- and directional-effects, we may then conclude as follows:

(1) The latitude intensity measurements of A. H. Compton and his associates give, from the sea level measurements, a diminution of 12 per cent[5] of the cosmic ray intensity in passing from high latitudes to the equator. For measurements at high altitudes, the corresponding change is 25 per cent.[6]

(2) The radiation of corpuscular nature which carries a positive charge is in excess of that carrying a negative charge.

(3) By combining the latitude variation in intensity, which depends upon the sum of the negative and positive corpuscular currents, with data on asymmetry, which are determined by the difference between these currents, T. H. Johnson is able to determine how much of each sign of current is involved. Confining attention to the sea level data on the latitude effect,

[4]For those who are unacquainted with the subject it must be remarked that relative intensities in different directions are obtained by an appliance which we may call a cosmic-ray telescope. A Geiger-Mueller counter comprises a hollow metal cylinder with a wire passing along the axis, the whole device being enclosed in glass and containing gas at reduced pressure. If the potential difference between the wire and the cylinder is adjusted to the right amount, the passage of a cosmic ray through the cylinder precipitates a discharge which may be amplified and recorded by suitable means. Suppose that three of these counters are arranged with their axes parallel and their centers on a line perpendicular to the axes, and suppose that the amplifying and recording mechanism is such that the final record is made only if all the counters discharge at once, then it is obvious that the system constitutes a cosmic-ray telescope which measures only those rays which come in such directions as to cause them to pass through all three cylinders.

[5]The 14 per cent quoted by Compton is expressed in terms of the intensity at the equator. A similar remark applies in the case of the 25 per cent cited later, which corresponds to Compton's 35 per cent of the equatorial intensity.

[6]It must be remarked that this 25 per cent and the 12 per cent cited above do not constitute a discrepancy. Both are lower limits, and the high altitude data give the larger value because they are more sensitive to the corpuscular nature of the rays, since they involve lower energy rays which have not been absorbed or had their potency for measurement reduced by the lower regions of the atmosphere.

it results that practically all of the corpuscular radiation which corresponds to energies sufficiently low to show a directional effect is of the positive type. While this result is not as inevitable when based solely upon the less accurate high altitude data for the latitude effect, it is in agreement with those data within the limits of their accuracy.

(4) The latitude effect gives us a lower limit for the amount of the corpuscular radiation. However, the limit obtained in this way does not include any corpuscular radiation of such an energy as can reach the earth at the magnetic equator. On the other hand the existence of an asymmetry at the equator enables one to add to the lower limit an additional corpuscular current. The net result is still only a lower limit, because it does not include any corpuscular current of energy so high that it would show no asymmetry effect at the equator. Proceeding according to these principles, and expressing percentages in terms of the total radiation of all kinds as measured at high latitudes, T. H. Johnson has been able to add 4.5 per cent to the 12 per cent resulting from A. H. Compton's latitude measurements at sea level. This would lead us to conclude from the sea level observations alone that at least 16 per cent of the intensity as measured at high latitudes is of the charged corpuscular nature. However, if we confine measurements to those at high altitudes, Dr. Johnson finds that the equatorial asymmetry data demand a minimum contribution of 6 per cent to the high latitude, high altitude intensity; and A. H. Compton's latitude measurements give a contribution of at least 25 per cent, so that these high altitude measurements demand a total contribution of 31 per cent as the minimum charged corpuscular contribution to the radiation.

The 31 per cent demanded for the corpuscular contribution is sufficient to "spoil" the exponential law provided so readily by the photon hypothesis unless the corpuscular hypothesis can itself be adapted to give that law. With the necessity of this adaptation facing us, it then naturally becomes of interest to see how far we can account for all of the cosmic-ray phenomena on the hypothesis that the primaries are of a corpuscular nature.

Difficulties Involved in Corpuscular Hypothesis:—According to the most naive views, the exponential law would have to be provided for in the corpuscular theory by the existence of a wide range of incoming corpuscular energies which penetrated

the atmosphere to different depths depending upon the energies of the individual rays concerned. The amount of radiation to be found at any depth below the top of the atmosphere would depend upon the number of incoming particles which happened to exist in the energy ranges necessary to reach the depth concerned; and the existence of an exponential law of absorption, or, if you prefer, of intensity with distance traversed, would necessitate the assumption of a special type of energy distribution in the incoming particles necessary to secure that law. Even though we accept the necessary assumptions, however, a great difficulty remains. For under the simple conditions postulated it would turn out that the quality of the radiation would be the same at all altitudes. By this I mean that if at sea level, for example, we should find a certain distribution of energy among the rays, then at higher altitudes one would find the same relative distribution. The number of rays having any given energy would be greater at the higher altitude; but rays of all energies would be greater in the same proportion. At first sight this result is contrary to our intuitions and is contrary to what has presumably been generally believed; for it is natural to argue that the rays at high altitude would contain a preponderatingly larger proportion of low-energy rays than would those at low altitudes, because the low-energy rays cannot penetrate to low altitudes. We must remember, however, that the rays which possessed high energy at high altitudes will, by process of absorption, become rays of low energy at low altitudes. They exist at low altitudes not because of the energy which they *have* there, but because of the energy which they *had* before they got there. If all of these matters are taken into account, then, as I have shown elsewhere, providing that one assumes the distribution of energies in outer space necessary to give the exponential law, it follows, as an inevitable consequence, that the quality must be the same at all altitudes.

Now the experimental data at our command resist, absolutely, harmonization with the view which concludes that the quality shall be independent of the altitude; for, upon such a view, the number of atomic bursts from lead, for example, would increase with altitude exactly in proportion to the measured number of cosmic rays themselves. Now such a conclusion is drastically contrary to some recent experiments of C. G. and D. D. Montgomery upon the frequency of these

bursts at high altitudes. For the Montgomeries have found that whereas the cosmic-ray intensity increases by a factor of five from sea level to the summit of Pike's Peak, the frequency of the atomic bursts increases by a factor of twenty-five. Similar results have been found by R. D. Bennett, G. S. Brown and H. A. Rahmel. Further, analogous conclusions follow from the experiments of T. H. Johnson and of B. Rossi and S. de Benedetti, upon small showers of secondary cosmic-rays produced by the primary cosmic radiation. Again recent measurements carried out in stratosphere flights[7] with Geiger counter apparatus designed by G. L. Locher and myself, when combined with data on the increase of intensity with altitude as measured by ionization chambers, have shown that the ionization produced by the rays in a closed vessel increases more rapidly with altitude than does the intensity of the rays itself, indicating once more a change of quality with altitude.

A New Form of Corpuscular Theory:—In order to overcome these difficulties, and at the sâme time secure the exponential law in what seems to be a more natural way, I have been lead to formulate a view as to the mechanisms of the processes involved which, in its simplest aspect, and to a first approximation, takes the following form. Let us suppose that primary rays of a single energy enter the atmosphere uniformly in all directions and that, as they travel through the atmosphere, they produce along their paths secondary rays possessing energies such as those which figure in cosmic-ray phenomena, but smaller than the energy of a primary ray. The secondary rays may be produced directly, or through a photon as intermediary. Let us suppose that these secondary rays are the chief entities which are observed in our cosmic-ray counters, and that they perpetuate the direction of the primaries which produce them. This last-named characteristic is hardly an assumption since it follows, as I have already shown, from the laws of impact in which both the primary and secondary particles have very high energies. In addition to this we shall assume, and this is the vital assumption, that the loss of energy per cm of path is proportional to the energy of the primary ray. Or, in other words, we shall assume that the number of secondaries per

[7]The first of these flights was made by Major W. E. Kepner, Capt. A. W. Stevens and Capt. O. A. Anderson. The second was made last fall by Prof. and Mrs. Jean Piccard.

cm of path is proportional to the energy of the primary. It is then clear that, even though all the primaries come right through the atmosphere so that the number of them passing through a square centimeter is the same at all altitudes, the measured effect, depending as it does upon the number of secondaries, will increase with altitude because of the increase of primary energy with altitude. When we submit the matter to calculation we find that the intensity as measured by the number of rays follows exactly that law which we have called the exponential law.

For, if the number of secondary rays produced per centimeter of path of the primary is proportional to the energy of the primary, then, if the secondaries perpetuate the paths of the primaries, the number of secondaries n_θ per unit area per unit solid angle corresponding to any zenith angle θ is

$$n_\theta = \alpha E \tag{1}$$

where E is the primary energy and α is a constant.

If the primaries lose energy entirely by the creation of secondaries, and if dx is an element of path of the primaries, and β a constant,

$$-\frac{dE}{dx} = \beta n_\theta = \beta\alpha E \tag{2}$$

So that

$$E = E_o e^{-\beta\alpha x} \tag{3}$$

Moreover, in view of (1)

$$n_\theta = (n_\theta)_o e^{-\beta\alpha x} \tag{4}$$

Again, (3) and (4) show that the apparent coefficient of absorption of the rays is independent of their energy, so that, without disturbing the exponential law, it is possible to permit the primary rays to possess a wide range of energies, and thus to remove one of the postulates which, at first sight, it might seem necessary to make. All energies give, in fact, an exponential law with the same coefficient of absorption.

The main feature of the foregoing theory is that, in it, the exponential law of absorption is secured as the result of the mechanisms of the processes taking place in the atoms, the emission of secondaries, and does not rely upon some peculiar distributions of energies among the incoming rays. Again, having secured now a variation of quality with altitude, we are well prepared to see in a natural way how such experiments as

those of the Montgomeries can be accounted for. Thus while we suppose that the law of production of secondary rays from the *air* is one which makes the number produced under assigned conditions proportional to the energy of the primary rays, let us suppose that in the case of *lead*, the rate of production of those secondaries which we call cosmic-ray bursts is proportional to a higher power of the energy than the first. Suppose, for example, that doubling the energy of the primary rays gives us four times the number of bursts. Then it is easy to see that, as in the case of the experiments of the Montgomeries, if the measured cosmic-ray intensity increases by a factor of five from sea level to the top of Pike's Peak, the number of bursts will increase by a factor of twenty-five. Moreover, in a more detailed form of the theory, we may well expect that the nature of the secondary rays produced from air will depend to some extent upon the energies of the primaries. In fact, the secondaries themselves may, in certain cases. arise not directly from the primaries but through the intermediacy of photons produced by the primaries, which photons in turn eject the electrons as secondaries from the atoms of air. There is thus ample provision for the situation found in which the ionization in a closed vessel varies with altitude in a manner different from that for the intensity of rays as measured by counters, since the ionization is produced by the secondaries and even by other entities, as neutrons, etc., which may be liberated by the primaries.

It will be observed that the foregoing simple theory makes the coefficient of absorption of the energy the same as that of the measured intensity, when the intensity is measured by the numbers of the secondary rays. This fact is of interest because it suggests between the energies of the rays entering the atmosphere and the energies as measured at sea level, a relation calculable in terms of the relation between the cosmic-ray intensity at, or near, the top of the atmosphere and the corresponding intensity at sea level. The recent stratosphere flight made by Major W. E. Kepner, Capt. A. W. Stevens, and Capt. O. A. Anderson, and also that made by Professor and Mrs. Jean Piccard, both with Geiger counter apparatus designed by G. L. Locher and the writer, agree in showing that the vertical intensity, when extrapolated to the top of the atmosphere, is about 90 times the sea level value. The minimum electron energy necessary to permit vertical entry

in opposition to the earth's magnetic field in these latitudes, is about 4.5×10^9 volts. The corresponding sea level value would consequently be about 5×10^7 volts. This is a reasonable value in the light of the requirements demanded of it. The energy necessary for vertical entry at the equator is about 3×10^{10} volts, and if we could assume the same law of increase of intensity with altitude at the equator as at these higher latitudes, the corresponding minimum sea level energy for the primaries would be about 3×10^8 volts. Of course, these are only *minimum* values for the energies of the vertical rays, and higher energies at entrance will correspond to higher sea level energies. Apart from any other considerations, however, the principle here exemplified is sufficient to explain why cloud chamber experiments made, of course, at low altitudes, have failed to reveal corpuscular energies as great as those which would be suggested by consideration of the requirements of the earth's magnetic field. Moreover, consideration of these matters serves to emphasize the importance of cloud chamber energy measurements at high altitudes.

An element of difficulty exists from a consideration of the case of rays which are inclined appreciably to the vertical, and which at entry are of sufficiently low energy to show azimuthal asymmetry. These rays, traveling as they do through distances in the atmosphere considerably greater than the vertical rays, would be expected to become reduced in energy at sea level to values below those permissible for the performance of their functions. This difficulty tends to disappear in a more complete formulation of the theory to which brief reference will now be made.

Extension of the Theory:—While the foregoing simple form of theory correlates the more immediately obvious phenomena, it requires modification in detail. That very feature which gives the power to predict an exponential law—the feature which causes the percentage rate of absorption of energy to be independent of the energy—is one which, in its exact form, denies a fact characteristic of the azimuthal asymmetry effect, the fact that the percentage asymmetry increases with altitude. For this increase with altitude means that the primary rays which are responsible for the asymmetry, and which are therefore the rays of least energy, have a greater apparent coefficient of absorption than that which corresponds to the average radiation. In other words we must admit an increase of absorbability with

decrease of energy. Such a provision may be made purely empirically. Thus, if (1) be modified to the form

$$n_\theta = \alpha E^{1-\lambda} \tag{5}$$

where λ is a constant, (2) assumes the form

$$-\frac{dE}{dx} = \beta\alpha E^{1-\lambda}$$

and, if we define the coefficient, μ_e of absorption of the energy at any point as $-(1/E)\ (dE/dx)$, we find

$$\mu_e = \beta\alpha E^{-\lambda}$$

We are concerned more particularly with the measured coefficient of absorption μ_n, defined as—$(1/n_\theta)\ (dn_\theta/dx)$. In view of (5)

$$\mu_n = (1-\lambda)\ \mu_e$$

so that on the basis of the hypothesis under consideration, both μ_n and μ_e increase with decrease of energy.

The result may be secured in another way, having a more direct physical significance. For if, leaving (1) unchanged, we replace (2) by

$$-\frac{dE}{dx} = \beta n_\theta + \gamma \tag{6}$$

the quantity γ represents a constant loss of energy per centimeter of path all along the path of the primary. It is symbolized, for example, by such a loss as is represented by ordinary ionization.

Combining (1) and (6) we thus obtain

$$\mu_e = \beta\alpha + \gamma/E \tag{7}$$

and observing from (1) that $\mu_n = \mu_e$, we have

$$\mu_n = \beta\alpha + \gamma/E$$

which again gives an expression which causes μ_n to increase with decrease of E.

It is of interest to observe in general that if (1) be modified to

$$N_\theta = \alpha E^s \tag{8}$$

$$\mu_n = s\ \mu_e$$

so that if s is greater than unity, μ_n is greater than μ_e. Such a provision has an advantage in causing the ratio of the energy

of the rays entering the atmosphere to the energy of the rays at sea level to be less than the ratio of the corresponding measured cosmic-ray intensities. This consequence lessens the difficulties already referred to in the matter of the asymmetric rays, concerning the entering energies as computed from the earth's magnetic field, and the sea level energies as computed from the entering energies and the coefficient of absorption.

The incorporation of (8) into the theory as represented by (6), leads to

$$\mu_e = \beta\alpha E^{s-1} + \gamma/E$$

and

$$\mu_n = s\beta\alpha E + s\gamma/E$$

This expression represents a μ_n which increases with decrease of E for low values of E, but which decreases with decrease of E for high values of E.

A further remark must be made concerning the fact that in so far as there is a departure from the exponential law of absorption in the atmosphere, that departure is in the direction of a hardening of the rays as they approach the earth. At first sight this fact is contrary to the principle that the effective coefficient of absorption of the rays increases as the rays lose energy—a principle demanded by the asymmetry effect. The difficulty is only transitory, however; for, now, we introduce once more the idea of a wide range of primary energies entering the atmosphere, a hypothesis which is indeed required by the latitude and directional effects. Then, although each of these rays may *soften* as a result of its passage through the atmosphere, a suitably chosen energy distribution among the entering rays will insure that the measured radiation as a whole will harden with approach to sea level. The matter may be illustrated by considering the case of two distinct energies entering the atmosphere. Let the first, denoted by subscript unity, be the higher energy. For purposes of illustration we shall write, for some assigned direction,

$$n_1 = n_{10} e^{-\int \mu_1 dx}$$

This rather artificial looking expression is adopted because it corresponds to a coefficient of absorption, defined as $-(1/n_1)\,(dn_1/dx)$ which is equal to μ_1 and is variable with x, if μ_1 varies with x.

In a similar manner, we write

$$n_2 = n_{20}e - \int \mu_2 dx$$

The contribution of the two types of radiation is given by

$$n = n_1 + n_2 = n_{10}e^{-\int \mu_1 dx} + n_{20}e^{-\int \mu_2 dx}$$

The average coefficient of absorption of the combined radiation may be defined as $\mu = -(1/n)\ (dn/dx)$, so that

$$\mu = \frac{\mu_1 n_1 + \mu_2 n_2}{n_1 + n_2}$$

To illustrate the properties of this expression it will be sufficient to remark that if at x = 0, i. e., at entry to the atmosphere, n_1 is small compared to n_2, μ approximates μ_2. On the other hand at sufficiently large values of x, the quantity n_1 is large compared with n_2 on account of the required assumption that μ_2 shall be greater than μ_1. Hence at large values of x, the coefficient μ approximates μ_1. Thus, under the condition cited we have an illustration of the fact that. while the individual quantities μ_1 and μ_2 both increase with x, the measured μ decreases from μ_2 to μ_1, with increase of x.

It is not my purpose to attempt to fix too definitely, at this stage, the exact forms of the details of the various elements of the corpuscular theory here presented. It will suffice to say that, within the general spirit of the ideas outlined in the elementary form of the theory, it is possible to make modifications which will include all the experimental facts concerned with absorption in the atmosphere, and with the latitude and directional effects. By the farther hypothesis already cited, and to the effect that in the case of heavy atom elements, frequency of shower production and the like depend upon a higher power of the primary energy than the first, we are able to correlate with theory the experiments already cited in relation to such phenomena, together with a number of other experiments relating shower production to altitude, and to the characteristics of the primary rays as determined by their direction, or by their behavior in the matter of asymmetry.

In the foregoing discussion we have taken as the measured intensity, the intensity determined by the secondaries. We may regard each primary as accompanied by a number of secondaries equal to the product of the number emitted per

centimeter of path and the range of the secondaries. It is this latter quantity which, in the foregoing theory, determines the contribution of a simple primary to the measured intensity. If the primary itself ionizes, the contribution in question should be increased by unity. This does not disturb the essentials of the theory, however.

It is of interest to note that if q is the number of secondaries produced per centimeter of path by a primary, and if each secondary has an energy of 10^8 electron volts, the loss of energy per centimeter of path would be $q \times 10^8$. On the other hand, the loss of energy per centimeter of path at a place where the primary energy is E, is, according to the elementary theory, equal to μE, where μ is the absorption coefficient. Estimating all lengths in terms of centimeters of air compressed to the density of water, we have $\mu = 0.005$. Hence, $q \times 10^8 = 0.005\,E$. If E is of the order 10^{10} electron volts, $q = 0.5$. The range of 10^8 volt secondaries is of the order 20 cms in air compressed to the density of water. Hence the number of electrons accompanying each primary at the place where the primary energy is 10^{10} volts is of the order $20 \times 0.5 = 10$. The question of whether the primary is, or is not, added becomes therefore of small importance; although the importance is increased for smaller primary energies.

Any difficulty concerned with the participation of the primaries in direct ionization may be removed by a modification of the theory in which what we have already regarded as the primaries are really photons in their journey through the atmosphere. We must suppose that these photons receive their energy and their directional characteristics in their creation from the real charged particle primaries by impact of the latter with the atoms of air in the higher regions of the atmosphere. If then we impute to the photons the same characteristics of shower production, energy loss, etc., as we have imputed to the primaries in the foregoing discussion, the whole theory already given follows again in all its essential details. As the photons lose energy their frequencies of course change.

Possible Effects of Non-Ionizing Primaries:—The question of whether the high-energy primaries do, or do not, ionize is one which has interesting significance in another connection. Many years ago I was lead to study it in connection with the replenishment of the earth's charge. Through the action of

the conductivity of the atmosphere, the earth is sending off its charge into space at such a rate that 90 per cent of the charge would disappear in 10 minutes, if there were no means of replenishing the loss. A whole class of theories to account for the replenishment invoke, in some form or other, the principle of an influx of high-energy electrons into the earth. In order to account for the continual replenishment it is necessary to assume that 1,500 electrons enter each square centimeter of the earth's surface per second. If these electrons ionized air at the normal rate characteristic of reasonably high-energy electrons, they would produce 60,000 ions per cc. per second, whereas in practice we find less than 10 ions per cc. per second. For this reason I sought a theoretical mechanism by which it might be possible to conclude that a charged particle of sufficiently high energy would fail to ionize. In terms of the classical theories of electrodynamics it was found possible, satisfactorily, to realize such a theoretical possibility. With the advent of the wave mechanics I sought some means by which such a situation could be evolved out of that form of theory also. It was found possible to introduce in a natural way an extension of the wave mechanical principles to permit of such a possibility, and recently this extension has been put out and published in detailed form. At my request Dr. Bramley has applied the modified wave mechanical theory to the problem of ionization so as to work out the preliminary details of the mathematical mechanism by which the ionization for high energies becomes suppressed.

More recently the possibility that very high energy particles might not ionize received a renewed interest from the fact that cloud chamber measurements apparently failed to reveal as many high-energy electrons as would be demanded by the magnetic effects, a fact which could be understood if the high-energy electrons failed to ionize. A further field of interest in the matter concerns recent experiments by J. Clay on the intensity of cosmic radiation at various depths below the surface of water. Fig. 3 represents Clay's results on measurements of the ionization produced in a closed vessel at various depths. The ordinates represent the ratio of the ionization to the ionization at sea level. The significant thing about these observations is the fact that with increasing depth, the ionization diminishes, but at 100 meters of water, the curve starts to flatten out and actually shows a rise at 250 meters,

falling finally to zero at about 270 meters. It is possible to understand this state of affairs if we invoke the idea that the primary agency is a charged particle which does not ionize directly, but only through the intermediary of secondaries, but which, as it loses its energy, comes finally to an energy at which it commences to ionize directly. In this range of energy, it has a short period of renewed activity, represented by the hump at 250 meters in Fig. 3; but this activity represents as it were the dying gasp of the ray; for, at this stage its energy has reached a value at which its subsequent path in water is limited to twenty or thirty meters, after which its active life is spent. The complete story of the matter is a little more complicated than is here implied[8] but the details serve to enhance more than to detract from the reasonableness of the explanation.

Origin of Charged Particle Energy

The origin of charged particles of energies comparable with 10^{10} volts presents, of course, an interesting field for speculation. If the particles come from the stars, it is reasonably certain that positives and negatives must be emitted in equal numbers; for, if not, a star would soon become charged to an enormous potential which would prevent further departure. Thus, if the sun emitted from its surface no more electrons per square centimeter per second than fall per square centimeter per second on the surface of the earth as electron cosmic rays, it would charge at the rate of about 3×10^{10} volts per year. Since both signs must be emitted equally in the steady state, it is obvious that neither sign of charge can receive its energy from a potential field originating in the emitting body; and symmetrical from all parts of that body; for a field which would promote the departure of one sign would prevent the departure of the other.

A whole galaxy of stars with but small charge on each could, in the aggregate, secure for the galaxy a potential of large amount.[9] Consider a galaxy of radius R, containing N stars, each of radius a, and charged to a potential V in relation to a point sensibly infinitely distant from itself but yet falling

[8] W. F. G. Swann, The Significance of J. Clay's Ionization Depth Data in Relation to the Nature of the Primary Cosmic Radiation, Phy. Rev. 46, 432 (1934).

[9] W. F. G. Swann, "Methods of Acquirement of Cosmic Ray Energies," Phys. Rev. 42, 914 (1932); also "Cosmic Rays," The Military Engineer, 26, No 146, 116–120, March-April, 1934.

within the galaxy. It can readily be shown that the potential at the surface of the galaxy is $W = V_aN/R$. If n is the number of stars per unit volume, this amounts to $4\pi R^2V_an/3$. This increases rapidly with R for fixed values of V, a, and n, so that, for sufficiently large values of R, W may be made large compared with V and we may secure a high potential difference between the body of the galaxy and intergalactic space by the assumption of a relatively small value of V. Unfortunately, when applied to the actual condition in the known galaxies, the possibilities of size are not sufficiently great to enable us to secure values of W even as great as V.

Apart from this, however, in such a charged galactic system, charged particles could dive through the galaxy, but particles of both signs could not enter. Such a situation, however, would lead us into difficulties of another kind, for, as I have shown elsewhere[10] if we had in the space between the stars a density of particles moving with the velocity of light and such as to correspond to a cosmic ray intensity equal to that observable upon the earth, they would, if of one sign, produce a space charge such as to give rise to differences of potential of the order of 10^{18} volts between points in space separated by no more than one light year. At first sight one might think that this difficulty could be alleviated by the existence of a sort of space charge of low energy particles, of sign opposite to those of the high energy particles. However, so long as the resultant field is of the right kind to draw into the galaxy particles of one sign and produce high energy in them, it could not permit the entry of particles of the opposite sign unless they themselves had high energy before entering.

A possibility exists for the acquirement of high energies by charged particles without the invocation of large potential differences.[11] A change in magnetic field produces an electromotive force in any circuit through which the flux is changing. Now we know that sunspots are associated with magnetic fields and, therefore, it is easy to believe that such spots would exist on the stars. The magnetic field of a sunspot can grow to about 2,000 gauss in about 10 days. Without invoking the stellar spots themselves as origin of cosmic ray energies, I wish

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[10] W. F. G. Swann, "Space Density of Cosmic Ray Particles," Phys. Rev. 44, 124, (1933).

[11] W. F. G. Swann, "A Mechanism of Acquirement of Cosmic-Ray Energies by Electrons," Phys. Rev. 43, 217 (1933).

merely to use them as evidence of the existence of changing magnetic fields upon these stellar bodies. The practical fact then is that if, over the region of a star, we have an area whose diameter is comparable with fifty times the diameter of the earth, and in which a magnetic field is growing at a rate comparable with that at which it grows in a sunspot, then through the processes of electromagnetic induction, an electron would acquire an energy of 10^{10} volts in one second, and before the field has grown to more than one-thousandth of a gauss.

I may cite another possibility of a more speculative nature, but possessing nevertheless certain advantages.[12]. Many years ago, in order to provide an explanation of the earth's charge, of its magnetic field and several other matters, I proposed a modified scheme of electrodynamics. One of the consequences of this scheme was the prediction of a slow death of the positive charge in the case of a rotating body so that the surplus negative gradually accumulated until it built up a field in the atmosphere which insured that it passed away from the earth's surface at a constant rate such as would maintain equilibrium. If now, on the basis of this hypothesis we continue to trace the passage of electricity off into space, we see a growing volume distribution of electricity thinning out in density as we go outwards but continually increasing in total amount. This growing volume of electricity produces a difference of potential between the sphere and a point infinitely distant from it. If we allow the process to go on for an infinite time we find that the potential difference amounts to infinity, but the rate at which it mounts gets so slow as time goes on, that even astronomical times are not sufficient to result in more than differences of potential which, though large, are of an order of magnitude significant in cosmic ray phenomena. Thus if we should consider a star as large as the sun, with a surface density of current equal to that for the earth, we should find that in seventy years the potential difference between the star and infinity would have grown to about 6×10^9 volts. In order for it to grow to six times this amount 70 million years would be necessary, so that, as I have remarked, even the invocation of astronomical time would not lead to potentials which were out of the realm of reason. As a matter of fact, the actual situation arising out of the physical mechanism which this example is designed to

[12]W. F. G. Swann, "Cosmical Electrical Fields," Phys. Rev. 45, 295, (1934).

illustrate becomes complicated by various considerations involving the distances of the galactic systems from each other, the places of origin of cosmic rays, and so forth. All that I wish to emphasize is the possibilities inherent in a situation of this kind for the realization of potential differences of the order of magnitude comparable with those encountered in cosmic ray phenomena and such extrapolations into the regions of even higher energy as reason would permit.

Perhaps one of the easiest ways of accounting for the existence of high-energy particles is through the actions of phenomena analogous to thunderstorms in the stars. A thunderstorm is simply the result of the operation of a large electrical machine; and the fundamental principle of its operation is one in which positive and negative electrons are separated in amounts and through distances such as result in large difference of potential by using the tremendous forces of gravity acting on matter for the most part neutral. Even in the thunderstorm on earth, potential differences of the order of 10^9 volts can arise. An electron coming under the influence of the corresponding fields would become accelerated. Under suitable conditions, as C. T. R. Wilson has shown, it is possible for an electron to acquire energy in this way faster than it loses it to the surrounding gas. Moreover, the higher the energy of the electron, the less does it fritter away its energy. The electron is like a man who spends less and less as he acquires more and more wealth. Once the electron has surmounted its initial difficulties in getting started it can acquire energy equal to that determined by the potential differences available. Now, when we think of the enormous activities taking place in stars—particularly in novae, it would not be surprising if phenomena analogous to thunderstorms, or at any rate the essentials of an electrical machine, could exist on them such as would give rise to potential differences of the order of 10^{10} volts, or more. One need not make the mistake of thinking that because a star is neutral as a whole there cannot exist on it a point which has a finite electrical potential in relation to infinity. For in a system composed, for example, of two adjacent spheres equally charged, one positively and the other negatively, there is between the positive charge and infinity a difference of potential comparable in fact with M/r^2, where M is the moment of the combined spheres, and r is half the distance between them.

In case we look to the stars as the source of cosmic radiation it is natural to suppose that our sun is not in a condition to be a contributor; for, if it were, it would be natural to suppose that it was the main contributor in view of its proximity, just as it is the main contributor of light. Finally, however, one must make a remark to the effect that even if the sun did contribute an appreciable amount of the cosmic radiation in the form of charged particles, it would not be so easy to detect the fact as might be supposed; for, in view of the complicated influence of the earth's magnetic field, the contributions from various parts of space would have very little relation to any special increase of intensity in the geometrical direction of the sun itself.

Orientation in Science

The development and increasing popularity of orientation courses in science for college freshmen have created a need for textbooks to accompany such courses. This volume is the outcome of such a need. It is an attempt to give the student a rational and synoptic outlook upon man and the universe The evaluation of this particular effort presents the reviewer with a difficult task. The book contains much meat, but it is largely hidden in a mass of generalities and platitudes. At times it seems doubtful whether the student will be able to take away any specific facts at all; then in places the book is clearly and succinctly written, only to bog down again in a morass of meandering and essentially meaningless phraseology. The physical sciences are treated in much better fashion than the biological sciences. A particularly good point is the binding and cohesive development of evolution (cosmic, geological and organic) as a great unifying technique. Conversely, a particularly bad point is the constant untiring use of italics and quotation marks. All desirable emphasis is lost by the over-use of these potentially valuable forms of accent. Opening the volume at random, a typical page contains 65 words in italics and 17 words in quotation marks. This is a positive detraction. The book may appeal to the philosophically-minded student, but is not conducive to clear thinking or concrete orientation on the part of the many. In the opinion of this reviewer, the book defeats its own purpose.—L. H. S.

The Backgrounds and Foundations of Modern Science, by Richard E. Lee. xxv+536 pp. Baltimore, the Williams and Wilkins Co. 1935.

The Origin of the Solar System

For those who have become "universe-conscious" as a result of the writings of Jeans, Eddington and the rest, this well-written volume will provide the next step in adventures in cosmic thinking. It is a clear, stimulating account of the properties and workings of the sun, the planets, the satellites, the asteroids, the comets and the meteors. In technical difficulty it is a good step above the strictly popular volumes, but it is so clearly and directly written that the step is an easy one, and well worth the taking. The book represents the Page-Barbour Foundation Lectures given at the University of Virginia in 1934. The first two sections on the dynamical and physico-chemical properties of the solar system lead up to the important and thought-provoking third section, which discusses in detail the postulated theories of the origin of the system. Recent new and little-known data are presented, and the author's own hypothesis of origin is elaborated. After an hour or two of letting one's fancy roam afar in space and time, one ceases to worry about the expected letter that is three days overdue.—L. H. S.

The Solar System and its Origin, by Henry Norris Russell. 141 pp. New York, the Macmillan Co. 1935.

ENERGIES AND PRODUCTS INVOLVED IN NUCLEAR DISINTEGRATION AND SYNTHESIS

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INTRODUCTION

There seems to be running through the multitude of experiments that have been performed in the last year or so on nuclear disintegration, a strong demand for certain fundamental nuclear building blocks. These building blocks with their properties and their current scientific standing are listed in Table I (1).

TABLE I
BUILDING BLOCKS

	Mass	Charge	Symbol	Reputability
Electron	Very small	neg.	e	Long standing
Neutrino	Very small	zero	n'	Questionable
Positron.	Very small	pos.	$\overset{+}{e}$	Recently established
Negatron. . . .	Large	neg.	$\bar{p}$	Questionable
Neutron	Large	zero	n	Recently established
Proton	Large	pos.	p	Long standing

It is noticed that there are two major groups; a group of three with small masses and a group of three with large masses. The relative size of the masses in these two groups is about 1/1850 to 1.

A few years ago when only the two particles, the electron and the proton, were known, many attempts were made to build consistent arrays of the known nuclei out of these two constituents. However, when the reality of the neutron was established (2) and when sufficient experimental data on how nuclei disintegrate were accumulated, it became obvious that the previous concepts on nuclear building were inadequate and erroneous.

STABLE NUCLEI

Since only protons and neutrons (or combinations of these; for example, an alpha particle which consists, let us say, of two protons and two neutrons) are found ejected when a nucleus is made to disintegrate, it is natural to expect the nuclei of the various elements to be made up of a logical sequence of protons and neutrons (3). Table II shows a possible arrangement.

TABLE II

ATOMIC MASSES

	Composition	Bethe	Oliphant	Aston et al.
$_0n^1$	n	1 00850 (50)*	1 0083 (3)	1 0089
$_1H^1$	p	1 00807 (07)	1 0081 (1)	*1 0081*
$_1H^2$	n p	2 01423 (15)	2 0142 (2)	*2 0148*
$_1H^3$	n p n	3 01610 (33)	3 0161 (3)	3 0151
$_2He^4$	α	4 00336 (23)	4 0034 (4)	*4 0041*
$_2He^5$	α n	. .	5 010	5 0060
$_3Li^6$	α n p	6 01614 (50)	6 0163 (6)	6 0175
$_3Li^7$	α n p n	7 01694 (48)	7 0170 (7)	7.0176
$_4Be^8$	2α	. . . . .	8 007	.
$_4Be^9$	2α n	9 0135 (7)	9 0138 (5)	9 0164
$_5B^{10}$	2α n p	10 0146 (10)	10 0143 (3)	10 0135
$_5B^{11}$	2α n p n	11 0111 (11)	11 0110	11 0121
$_6C^{12}$	3α	12 0037 (7)	12 0027 (3)	*12 0048*
$_6C^{13}$	3α n	13 0069 (7)	. .	13 0051
$_7N^{14}$	3α n p	14 0076 (4)		14 0042
$_7N^{15}$	3α n p n	15 0053 (5)	.	15 0032
$_8O^{16}$	4α	16 0000 (0)	16 0000 (0)	16 0000
$_8O^{17}$	4α n	17 0040 (2)	.	17 0024
$_8O^{18}$	4α n n	.	.	18 0065
$_9F^{19}$	4α n n p	.		18 9931
$_2He^3$	p n p	3 01699 (46)	3 0172 (3)	3 0164

*The numbers in parentheses indicate the probable error; for example, 1.00850 + .00050.

First, there is the neutron and the proton separately. Next, there is the combination of neutron and proton, called the deuteron or nucleus of the heavy hydrogen atom of which heavy water is made. By adding a neutron to this nucleus there is obtained a still heavier nucleus of hydrogen. The addition of a proton to this nucleus then gives the alpha particle or the nucleus of the helium atom. It is obvious that the

nuclei following from here on may be arrived at by merely adding alternately a neutron and proton—until oxygen, atomic number 8, atomic weight 16, is reached. Then the scheme is to add neutron, neutron, proton, proton.

As may be seen in Table III this scheme continues to argon. Beyond argon a more complicated scheme involving the negatron seems to work more satisfactorily (4). In Table II are listed also the nuclear masses as given by three different workers. The masses given by the first two are based on nuclear disintegration data, the last based on mass spectrograph data (5). It is unfortunate that there is such a wide spread in the data available and that no definite values as yet can therefore be decided upon.

TABLE III

STABLE NUCLEI

Nucleus	Composition	Mass	Abundance
$_1H^1$	p	1 00807	99 99
$_1H^2$	n p	2 01423	025
$_1H^3$	n p n	3 01610	10^{-6}
$_2He^4$	α	4 00336	100
$_2He^5$	α n	5 010	. . . .
$_3Li^6$	α n p	6 01614	8 3
$_3Li^7$	α n p n	7 01694	91 7
$_4Be^8$	2α	8 007	05
$_4Be^9$	2α n	9 0135	99 99
$_5B^{10}$	2α n p	10 0146	20
$_5B^{11}$	2α n p n	11 0111	80
$_6C^{12}$	3α	12 0037	99 75
$_6C^{13}$	3α n	13 0069	25
$_7N^{14}$	3α n p	14 0076	99 86
$_7N^{15}$	3α n p n	15 0053	14
$_8O^{16}$	4α	16 0000	99 81
$_8O^{17}$	4α n	17 0040	.03
$_8O^{18}$	4α n n	18 0065	16
$_9F^{19}$	4α n n p	19 0031	100
$_{10}Ne^{20}$	5α	19 99671	90 4
$_{10}Ne^{21}$	5α n	. . . .	0 6
$_{10}Ne^{22}$	5α n n	21 99473	9 0
$_{11}Na^{23}$	5α n n p	.	100
$_{12}Mg^{24}$	6α	.	77 4
$_{12}Mg^{25}$	6α n	.	11.5
$_{12}Mg^{26}$	6α n n		11 1
$_{13}Al^{27}$	6α n n p	.	100
$_{14}Si^{28}$	7α	27 9818	94

TABLE III—(Continued)

Nucleus	Composition	Mass	Abundance
$_{14}Si^{29}$	7α n		4
$_{14}Si^{30}$	7α n n		2
$_{15}P^{31}$	7α n n p	30 9825	100
$_{16}S^{32}$	8α		96
$_{16}S^{33}$	8α n		1
$_{16}S^{34}$	8α n n		3
$_{17}Cl^{35}$	8α n n p	34 893	76
$_{18}A^{36}$	9α	35 976	0 6
$_{18}A^{37}$	9α n		
$_{18}A^{38}$	9α n n		
$_{19}K^{39}$	9α n n p		5.4
$_{18}A^{36}$	9α	35 976	0 6
$_{17}Cl^{37}$	9α *p*	36 980	24
$_{18}A^{38}$	9α *p* p		01
$_{18}A^{39}$	9α *p* p n		
$_{18}A^{40}$	9α *p* p n n	39 971	99 4
$_{20}Ca^{40}$	10α		97
$_{19}K^{41}$	10α *p*		94.6
$_{20}Ca^{42}$	10α *p* p		8
$_{20}Ca^{43}$	10α *p* p n		2
$_{20}Ca^{44}$	10α *p* p n n		2 3
$_{22}Ti^{44}$	11α		
$_{21}Sc^{45}$	11α *p*		100
$_{22}Ti^{46}$	11α *p* p		01
$_{22}Ti^{47}$	11α *p* p n		01
$_{22}Ti^{48}$	11α *p* p n n		99
$_{22}Ti^{49}$	11α *p* p n n n		.01
$_{22}Ti^{50}$	11α *p* p n n n n		01
$_{24}Cr^{50}$	12α 2n		4 9
$_{23}V^{51}$	12α 2n *p*		100
$_{24}Cr^{52}$	12α 2n *p* p		81 6
$_{24}Cr^{53}$	12α 2n *p* p n		10 4
$_{24}Cr^{54}$	12α 2n *p* p n n		3 1
$_{26}Fe^{54}$	13α 2n		95
$_{25}Mn^{55}$	13α 2n *p*		100
$_{26}Fe^{56}$	13α 2n *p* p		5
$_{26}Fe^{57}$	13α 2n *p* p n		
$_{26}Fe^{58}$	13α 2n *p* p n n		
$_{28}Ni^{58}$	14α 2n	57 942	66
$_{27}Co^{59}$	14α 2n *p*		100
$_{28}Ni^{60}$	14α 2n *p* p		34
$_{28}Ni^{61}$	14α 2n *p* p n		01
$_{28}Ni^{62}$	14α 2n *p* p n n		.01
$_{29}Cu^{63}$	14α 2n *p* p n n p		68
$_{30}Zn^{64}$	15α 4n	63 937	50 4
$_{29}Cu^{65}$	15α 4n *p*		32

TABLE III—(Continued)

Nucleus	Composition	Mass	Abundance
$_{30}Zn^{66}$	15α 4n *p* p		27 2
$_{30}Zn^{67}$	15α 4n *p* p n		4 2
$_{30}Zn^{68}$	15α 4n *p* p n n		17.4
$_{31}Ga^{69}$	15α 4n *p* p n n p		60
$_{30}Zn^{70}$	15α 4n *p* p n n p *p*	.	0 4
$_{32}Ge^{70}$	16α 6n		21.2
$_{31}Ga^{71}$	16α 6n *p*		40
$_{32}Ge^{72}$	16α 6n *p* p		27 3
$_{32}Ge^{73}$	16α 6n *p* p n	.	7.9
$_{32}Ge^{74}$	16α 6n *p* p n n		37 1
$_{33}As^{75}$	16α 6n *p* p n n p	74 934	100
$_{32}Ge^{76}$	16α 6n *p* p n n p *p*	... . .	6 5

NEUTRONS

By glancing over Table III several points of interest are noticed; for example, beryllium, atomic number 4, atomic weight 9, is the only nucleus with any appreciable abundance that has attached to its alpha-particle kernel only one single extra neutron. As might be expected this extra neutron (under violent bombardment with alpha rays from polonium) would easily be shaken loose and neutron emission observed. In fact this is the very way neutrons were first discovered by Chadwick in 1932. Consequently, were it not for the existence of this particular isotope of beryllium which copiously emits neutrons, the field of nuclear physics would undoubtedly be less advanced and less fruitful than it is today and nuclear physicists would be deprived of one of their most powerful tools for prying into the secrets of the nucleus.

Table IV has been prepared in order to show clearly what is meant by the terms *isotopes*, *isobars*, and *isomers*.

TABLE IV

ISOTOPES, ISOBARS, ISOMERS

	Weight of Nucleus	Chemical Properties of Atom	Structure of Nucleus	Examples
Isotopes	Different	Same	Different	$_1H^1$, $_1H^2$, $_1H^3$
Isobars	Same	Different	Different	$_1H^3$, $_2He^3$
Isomers	Same	Same	Different	$_{91}UX_2$,^{234} $_{91}UZ^{234}$

Since the advent of neutrons through the bombardment of beryllium by alpha rays, many attempts have been made to discover or develop other methods that would give strong neutron sources. The three most successful methods are deuteron bombardment of beryllium, deuteron bombardment of the heavier lithium isotope, and deuteron bombardment of deuterons. With four strong neutron sources available, much progress in nuclear transformations has been made by using the neutrons obtained from nuclear disintegration to bombard and thereby disintegrate other nuclei.

SYNTHESIZED RADIOACTIVE NUCLEI

When a nucleus is disintegrated, or rather transmuted, into some other nucleus, it frequently occurs that the nucleus which is formed is of a new species and has never been observed before. In order to show how fruitful this particular phase of the general nuclear problem is, there is collected in Table V a list of nuclei which were not known to either chemists or physicists before February, 1934. F. Joliot and I. Curie (6) announced then that alpha-ray bombardment of boron produces a product which is radioactive. This product is nitrogen, atomic number 7, atomic weight 13 (see eleventh row), composed of three alpha particles and one proton, has a half life of 11 minutes, emits positrons with energies up to 1.5 million volts, and as may be seen in the last column of the table, can be produced also by proton bombardment of carbon or by deuteron bombardment of carbon.

TABLE V

SYNTHESIZED RADIOACTIVE NUCLEI

Nucleus	Composition	Life	Energy of e	+ or —	Method of Production
${}_2He^3$	p n p	.	.		p Li^6; d (H^2, B^9)
${}_2He^6$	α n n	.	. . .		. . .
${}_3Li^5$	α p	. . . .		.	.
${}_3Li^8$	α n n p n	0 5 s	9. mV max	—	d Li^7
${}_4Be^7$	α p n p		. . . . .		. . . .
${}_4Be^{10}$	2α n n		3 mV av	—	d Be^9; α Li^7
${}_5B^9$	2α p	1 m	5 mV av	+	α Li^6
${}_5B^{12}$	2α n n p n	02 s	11 mV max	—	d B^{11}
${}_6C^{11}$	2α p n p	20 m	1 3 mV max	+	d B^{10}
${}_6C^{14}$	3α n n	. . . . .	. . .	.	. . .
${}_7N^{13}$	3α p	11 m	1 5 mV max	+	p C^{12}; d C^{12}; α B^{10}

TABLE V—(Continued)

Nucleus	Composition	Life	Energy of e	+or—	Method of Production
${}_{7}N^{16}$	3α n n p n	9 s	.	—	n F^{19}
${}_{8}O^{15}$	3α p n p	126 s	1 2 mV max	+	d N^{14}
${}_{8}O^{19}$	4α n n n	40 s	. . . .	—	n F^{19}
${}_{9}F^{17}$	4α p	1 16 s	.	+	α N^{14}
${}_{9}F^{18}$	4α n p	. . .		+	
${}_{9}F^{20}$	4α n n p n	12 s	4 5 mV max	—	n Na^{23}; d F^{19}
${}_{10}Ne^{19}$	4α p n p	.	. .	+	.
${}_{10}Ne^{23}$	5α n n n	40 s	. .	—	n (Na^{23}, Mg^{26})
${}_{11}Na^{22}$	5α n p	. .	4 mV av	+	α F^{19}
${}_{11}Na^{24}$	5α n n p n	15 h	1 0 mV av	—	n (Na^{23}, Mg^{24}, Al^{27}) d Na^{23}
${}_{12}Mg^{23}$	5α p n p		. . . .	+	. .
${}_{12}Mg^{27}$	6α n n n	10 m	6 mV av	—	n (Mg^{26}, Al^{27})
${}_{13}Al^{26}$	6α n p	.	.	+	
${}_{13}Al^{28}$	6α n n p n	2 3 m	1 3 mV av	—	n (Al^{27}, Si^{28}, P^{31}); d Al^{27}; α Mg^{25}
${}_{14}Si^{27}$	6α p n p	14 5 m	. . . .	+	α Mg^{24}
${}_{14}Si^{31}$	7α n n n	2 4 h	1.25 mV av	—	n (Si^{30}, P^{31})
${}_{15}P^{30}$	7α n p	3 25 m	3 mV max	+	α Al^{27}
${}_{15}P^{32}$	7α n n p n	14 d	8 mV av	—	n (S^{32}, Cl^{35})
${}_{16}S^{31}$	7α p n p			+	
${}_{16}S^{35}$	8α n n n			—	
${}_{17}Cl^{34}$	8α n p			+	
${}_{17}Cl^{36}$	8α n n p n	50 m	2 mV max	—	n Cl^{35}
${}_{17}Cl^{38}$	9α *p* n		. . .	—	n Cl^{37}
${}_{18}A^{35}$	8α p n p			+	
${}_{18}A^{39}$	9α n n n			—	
${}_{19}K^{38}$	9α n p			+	
${}_{19}K^{42}$	10α *p* n	16 h	1 6 mV av	—	n (K^{41}, Sc^{45}, Ca^{42})
${}_{20}Ca^{41}$	10α n	4 h	.	—	n Ca^{40}
${}_{20}Ca^{45}$	10α *p* p n n n	3 m		—	n Ti^{48}
${}_{21}Sc^{46}$	11α *p* n	. .		. . .	n Sc^{45}
${}_{23}V^{52}$	. . . .	3 75 m	1 4 mV av	—	n (V^{51}, Cr^{52}, Mn^{55})
${}_{25}Mn^{56}$	. . .	2 5 h	1 2 mV av	—	n (Mn^{55}, Fe^{56}, Co^{59})
${}_{29}Cu^{64}$	. . . . .	5. m	. . . .	—	n (Cu^{63}, Zn^{64})
${}_{29}Cu^{66}$	. . .	10 h	.	—	n (Cu^{65}, Zn^{66})
${}_{31}Ga^{70}$	. . .	20 m	1 4 mV av	—	n Ga^{69}
${}_{31}Ga^{72}$	. . . . .	23 h	. . . .	—	n Ga^{71}
${}_{32}Ge^{75}$		30 m	. . .	—	n Ga^{74}
${}_{33}As^{76}$	. .	26 h	1 3 mV av	—	n As^{75}
${}_{34}Se^{81}$	. .	35 m	. . . .	—	n Se^{80}
${}_{35}Br^{80}$	.	30 m	2 1 mV max	—	n Br^{79}
${}_{35}Br^{82}$	.	6 h	2 1 mV max	—	n Br^{81}
${}_{40}Zr^{95}$	. .	4 h	1 1 mV av	—	n Zr^{94}
${}_{42}Mo^{99}$	.	30 m	. .	—	n Mo^{98}
${}_{42}Mo^{101}$	. .	36 h	. .	—	n Mo^{100}

TABLE V—(Continued)

Nucleus	Composition	Life	Energy of e	+or—	Method of Production
$_{45}$Rh	.	44 s	1 2 mV av	—	n Rh
$_{45}$Rh	.	3 9 m	. .. ...	—	n Rh
$_{47}Ag^{108}$	.	22 s	... .	—	n Ag^{107}
$_{47}Ag^{110}$	.. .. . .	2 3 m	7 mV av	—	n Ag^{109}
$_{49}In^{114}$	. ..	54 m	7 mV av	—	n In^{113}
$_{49}In^{116}$	.	3 h	. . ..	—	n In^{115}
$_{51}Sb^{122}$	. .. .	2 5 d	7 mV av	—	n Sb^{121}
$_{52}Te^{131}$	. . .	45 m	....	—	n Te^{130}
$_{53}I^{128}$	. . .. .	30. m	2 1 mV max	—	n I^{127}
$_{55}Cs^{134}$	. ..	1 5 h	.. .	—	n Cs^{133}
$_{56}Ba^{139}$	. .. . ..	80 m	. . ..	—	n Ba^{138}
$_{58}Ca^{141}$		5 m	.....	—	n Pr^{141}
$_{59}Pr^{142}$	.	19. h	1 mV av	—	n Pr^{141}
$_{60}Nd^{147}$	. . .	1 h	.. ..	—	n Nd^{146}
$_{62}Sm^{153}$	.	40 m	.. .	—	n Sm^{152}
$_{64}Gd^{159}$		8. h	..	—	n Gd^{158}
$_{72}Hf^{181}$		2. mo	. . .	—	n Hf^{180}
$_{74}W^{185}$	.	1. d	. .. ..	—	n W^{184}
$_{75}Re^{186}$		20 h	1 mV av	—	n Re^{185}
$_{77}$Ir	. . .	19 h	1. mV av	—	n Ir
$_{78}$Pt	. .	50. m	.. ..	—	n Pt
$_{79}$Au		2 7 d	4 mV av	—	n Au
$_{90}$Th	. . . . .	1 m	.. . .	—	n Th^{232}
$_{90}$Th	. . . .	24 m	. . . ...	—	n Th^{232}
$_{92}$U	. ... .	15 s	.. ..	—	n U^{238}
$_{92}$U	. . . .	40 s	....	—	n U^{238}
?	. .	13 m	1.2 mV av	—	n U^{238}
?		100 m	.6 mV av	—	n U^{238}

Helium, atomic number 2, atomic weight 3 (see first row), has not been observed to be radioactive, nevertheless it is listed in this table with the synthesized nuclei because it fits in with their scheme of nuclear composition. Every nucleus in this table does not fit in with the scheme for stable nuclei in Table III. However, there apparently is no great fundamental difference between stable nuclei and unstable nuclei since the half life of the synthesized nucleus hafnium is two months.

It is interesting to notice that the lighter synthesized nuclei can be obtained in several ways while the heavier synthesized nuclei must be obtained only with neutron bombardment (7). To make somewhat more clear the implication of the shorthand of the last column of Table V, there is written out in

Table VI the details for the various ways in which radioactive sodium, or rather radio-sodium, can and may be synthesized. Similar information in regard to radio-aluminum is given in Table VII. The upper group of reactions in each of these tables are those reactions that have been observed to work satisfactorily; the lower group are those that might work if the various nuclei involved existed or existed in sufficient abundance.

TABLE VI

RADIO-SODIUM

$$\left.\begin{array}{lll}
{}_0n^1 + {}_{11}Na^{23} & \longrightarrow & {}_{11}Na^{24} \\
{}_0n^1 + {}_{12}Mg^{24} & \longrightarrow & {}_{11}Na^{24} + {}_1p^1 \\
{}_0n^1 + {}_{13}Al^{27} & \longrightarrow & {}_{11}Na^{24} + {}_2He^4 \\
{}_1d^2 + {}_{11}Na^{23} & \longrightarrow & {}_{11}Na^{24} + {}_1p^1 \\
 & & \\
{}_1d^2 + {}_{12}Mg^{26} & \longrightarrow & {}_{11}Na^{24} + {}_2He^4 \\
{}_2\alpha^4 + {}_{10}Ne^{21} & \longrightarrow & {}_{11}Na^{24} + {}_1p^1 \\
{}_2\alpha^4 + {}_9F^{21} & \longrightarrow & {}_{11}Na^{24} + {}_0n^1 \\
{}_1d^2 + {}_{10}Ne^{23} & \longrightarrow & {}_{11}Na^{24} + {}_0n^1 \\
{}_1p^1 + {}_{10}Ne^{24} & \longrightarrow & {}_{11}Na^{24} + {}_0n^1 \\
{}_1p^1 + {}_{12}Mg^{27} & \longrightarrow & {}_{11}Na^{24} + {}_2\alpha^4
\end{array}\right\} {}_{11}Na^{24} \xrightarrow[15h]{} {}_{12}Mg^{24} + {}_{-1}e^0$$

TABLE VII

RADIO-ALUMINUM

$$\left.\begin{array}{lll}
{}_0n^1 + {}_{13}Al^{27} & \longrightarrow & {}_{13}Al^{28} \\
{}_0n^1 + {}_{14}Si^{28} & \longrightarrow & {}_{13}Al^{28} + {}_1H^1 \\
{}_0n^1 + {}_{15}P^{31} & \longrightarrow & {}_{13}Al^{28} + {}_2He^4 \\
{}_1d^2 + {}_{13}Al^{27} & \longrightarrow & {}_{13}Al^{28} + {}_1H^1 \\
{}_2\alpha^4 + {}_{12}Mg^{25} & \longrightarrow & {}_{13}Al^{28} + {}_1H^1 \\
 & & \\
{}_1d^2 + {}_{14}Si^{30} & \longrightarrow & {}_{13}Al^{28} + {}_2He^4 \\
{}_1d^2 + {}_{12}Mg^{27} & \longrightarrow & {}_{13}Al^{28} + {}_0n^1 \\
{}_2\alpha^4 + {}_{11}Na^{25} & \longrightarrow & {}_{13}Al^{28} + {}_0n^1 \\
{}_1p^1 + {}_{12}Mg^{28} & \longrightarrow & {}_{13}Al^{28} + {}_0n^1 \\
{}_1p^1 + {}_{14}Si^{31} & \longrightarrow & {}_{13}Al^{28} + {}_2He^4
\end{array}\right\} {}_{13}Al^{28} \xrightarrow[2.3m]{} {}_{14}Si^{28} + {}_{-1}e^0$$

If one is to prohibit electrons and positrons from being constituents in the building up of the nucleus, perhaps the necessity of accounting for the actual experimentally observed ejections of electrons and positrons from these radioactive nuclei would consequently produce some embarrassment. However, one is able to account satisfactorily for the emission of light from an atom without the necessity of saying that atoms are composed, in part at least, of light. Likewise, when a nucleus changes from one energy state to another of lower energy, the energy difference may be carried from the nucleus

in the form of a gamma ray or if there is sufficient excess energy in the form of an electron (or positron) which is created out of this energy in accord with the Einstein relativistic relation that energy equals mass multiplied by the square of the velocity of light.

SLOWED NEUTRONS

It is the common opinion that the faster the impinging bombarding particle is made to go, the more likely it is upon

TABLE VIII

SLOW-NEUTRON EFFECTIVENESS

Element Bombarded	Effectiveness of Slow Neutrons Over That of Fast
Vanadium	40
Silver	30
Manganese	23
Rhodium	15
Tungsten	15
Copper	15
Indium	12
Bromine	10

TABLE IX

ABSORBERS OF SLOW NEUTRONS (7)

Element	Thickness Required to Decrease Intensity of a Beam of Slow Neutrons to Half
Cadmium	.015 mm., .13 mm. (14)
Boron	.022 mm.
Yttrium	.040 mm.
Lithium	.094 mm.

collision for a disintegration to take place. This idea has recently been shown to be grossly wrong in a large number of the reactions where neutron bombardment is concerned. In Table VIII there are listed some of the elements which show a marked increase of effectiveness of slow neutrons compared to the effectiveness of fast neutrons in the production of radioactive nuclei (8). Other elements which do not yield radioactive nuclei when bombarded with neutrons evidence their reactional tendencies by strongly absorbing a beam of slow neutrons.

For example, the substances in Table IX are considered opaque to slow neutrons. However, some other substances such as aluminum, tin, zinc, and iron are comparatively transparent to slow neutrons. Almost all substances are easily penetrated by fast neutrons.

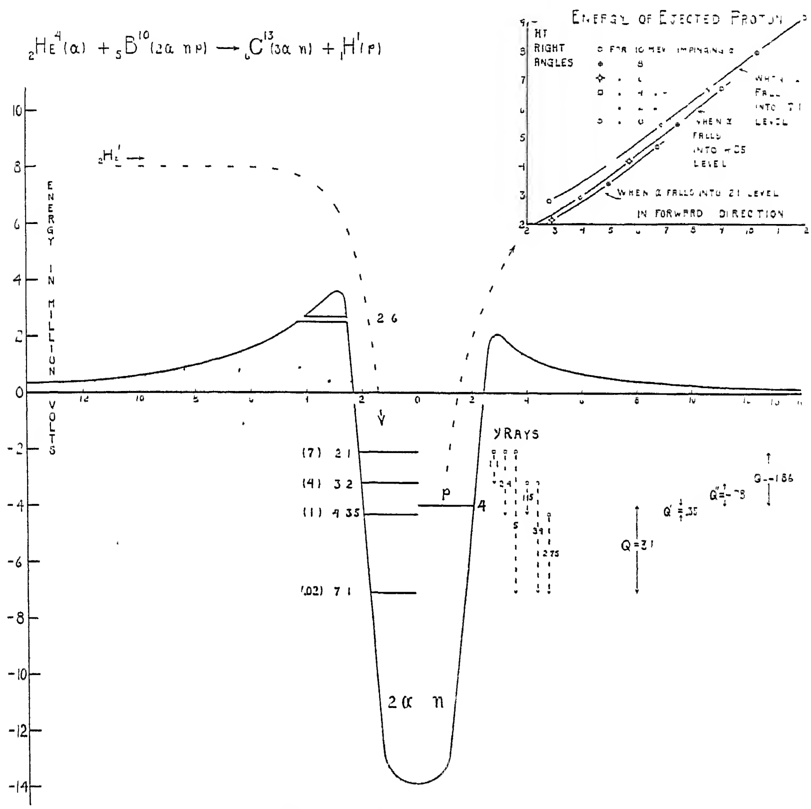

FIG. 1. Helium on Boron.

TRANSMUTATION DIAGRAMS

Since it is quite evident by now that there is a large quantity of information available concerning nuclear transmutations in general and concerning the behavior of any one nucleus in a transmutation, a collection, therefore, of a portion of this information condensed as much as possible into a single diagram or schematic picture would possibly be desirable.

With this purpose in mind consider Fig. 1 for the transmutation of boron into carbon and hydrogen (9). Along the

vertical axis is plotted energy in million volts and along the horizontal axis is plotted nuclear distance in 10^{-13} cm. The left half of the diagram represents the potential energy curve

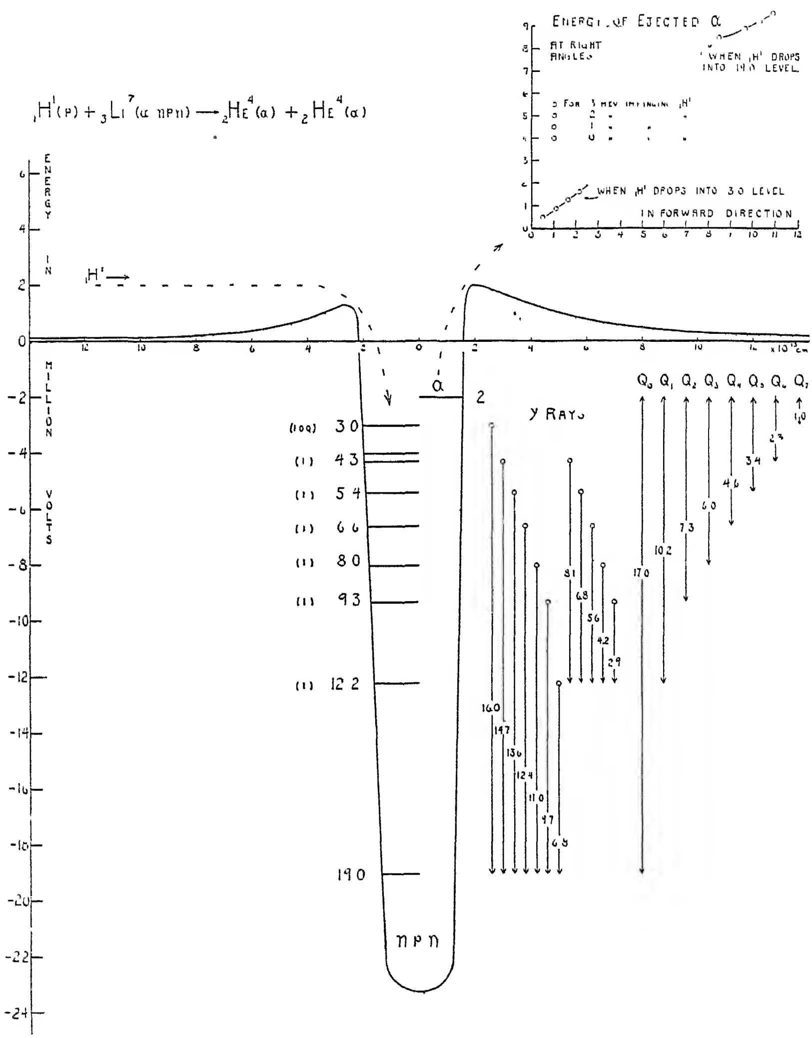

FIG. 2. Protons on Lithium.

or potential barrier of an alpha particle in the presence of a boron nucleus. This is the situation before the transmutation. The right-hand curve represents the potential energy curve or potential barrier of a proton in the presence of a carbon

nucleus. This is the situation after transmutation. The diagram is then to be read as follows: The alpha particle approaches the boron nucleus and is repulsed by the strong electric fields. If the alpha particle has enough energy to get over the barrier, which here is about 3.6 million volts, it then falls into the interior of the nucleus. There are four levels (2.1, 3.2, 4.35, and 7.1 million volt) on which the alpha particle may choose to stop. If the alpha particle drops to the lowest

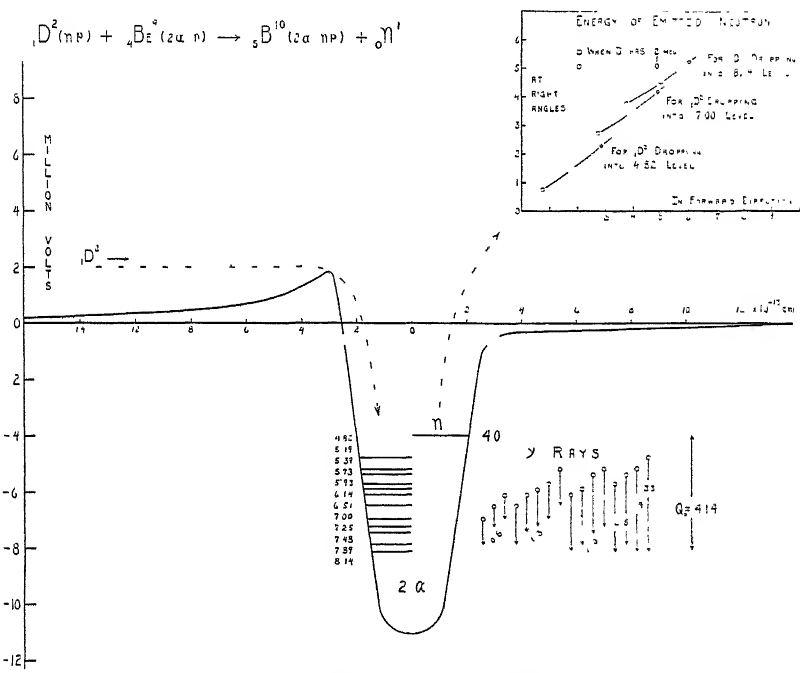

FIG. 3. Deuterons on Beryllium.

level, the greatest amount of energy is available to eject the proton from its four-million-volt level.

The proton may be ejected in the same direction as the impinging alpha particle or at right angles to this direction. Due to the conservation of momentum the proton will receive a little more energy if it comes off in the forward direction. Taking into consideration the momentum of the impinging alpha particle, the recoil of the residual carbon nucleus and the true transmutation energy Q, calculations were made for the energies of the protons in both the forward and the right-angle directions when the impinging alpha particle has various

energies up to ten million volts. These results are plotted in the inset graph where both the horizontal and vertical axes represent energy in million volts.

Consequently, if one wishes to know how energetically protons would be emitted at right angles when eight-million-volt

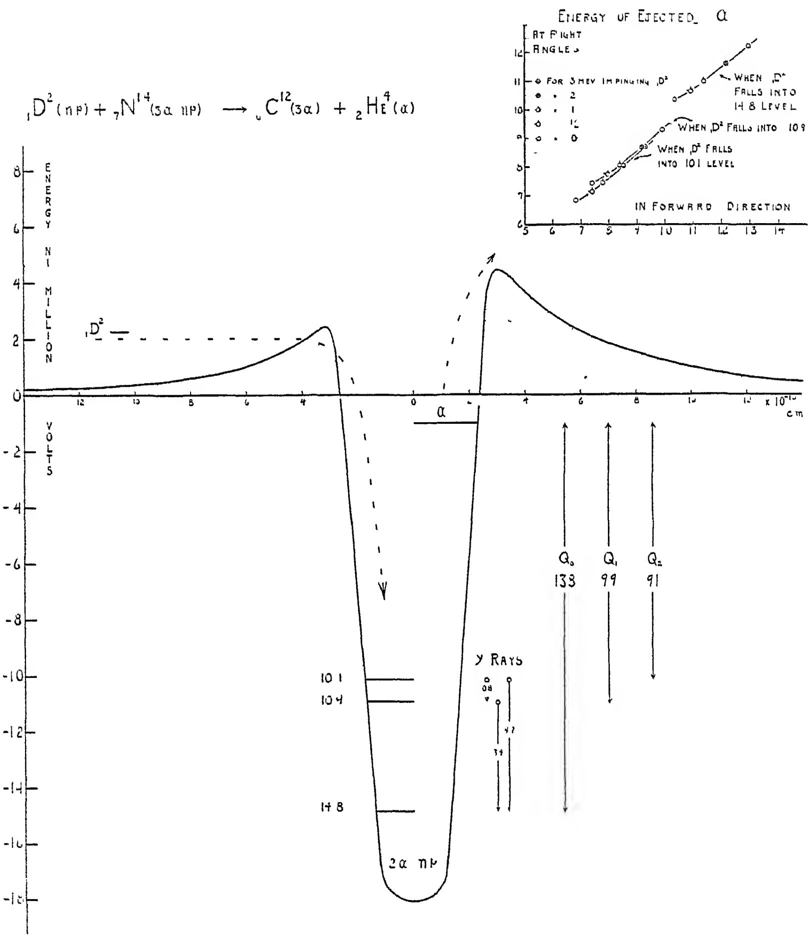

FIG. 4. Deuterons on Nitrogen.

alpha particles bombard boron, one can immediately see from the inset graph that there will be an eight-million-volt proton group if the alpha particles fall into the lowest level, or a 3.4-million-volt group if the alpha particles fall into the highest level. For protons emitted in the forward direction these two

numbers would be changed to 10.3 and 4.9, respectively. In general for a given alpha-particle energy, there are four proton groups emitted, since there are four levels into which the alpha particle may fall. The number in parentheses opposite each of these levels represents the relative chance that the alpha particle falls to that particular level.

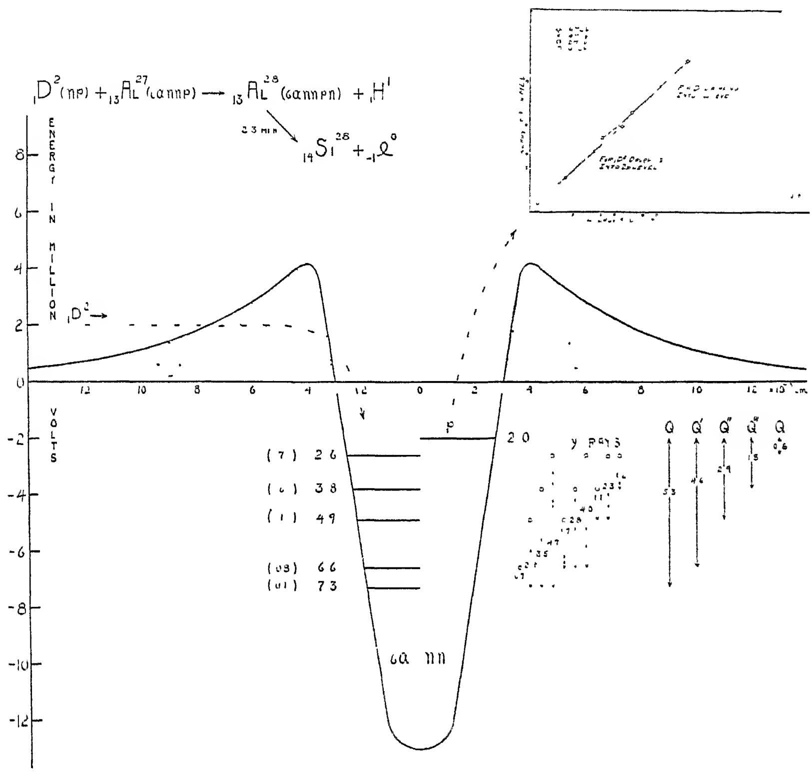

FIG. 5. Deuterons on Aluminum.

It seems to be true in this reaction as well as in most others that the impinging particle infrequently falls to the lowest level or ground level of the nucleus (10). When the alpha particle falls into a level other than the ground level the nucleus is thereby left in an excited state and later, perhaps in 10^{-20} sec., the alpha particle continues on down to the ground level. The energy difference is emitted as gamma ray. The possible gamma-ray energies are shown on the right side opposite the nuclear energy levels. In Fig. 1 all the transitions are dotted,

indicating that the expected gamma rays have not yet been observed. In some of the other figures gamma rays have been observed and are drawn in full line.

The true transmutation energy Q can be checked from the individual masses. For example, before transmutation

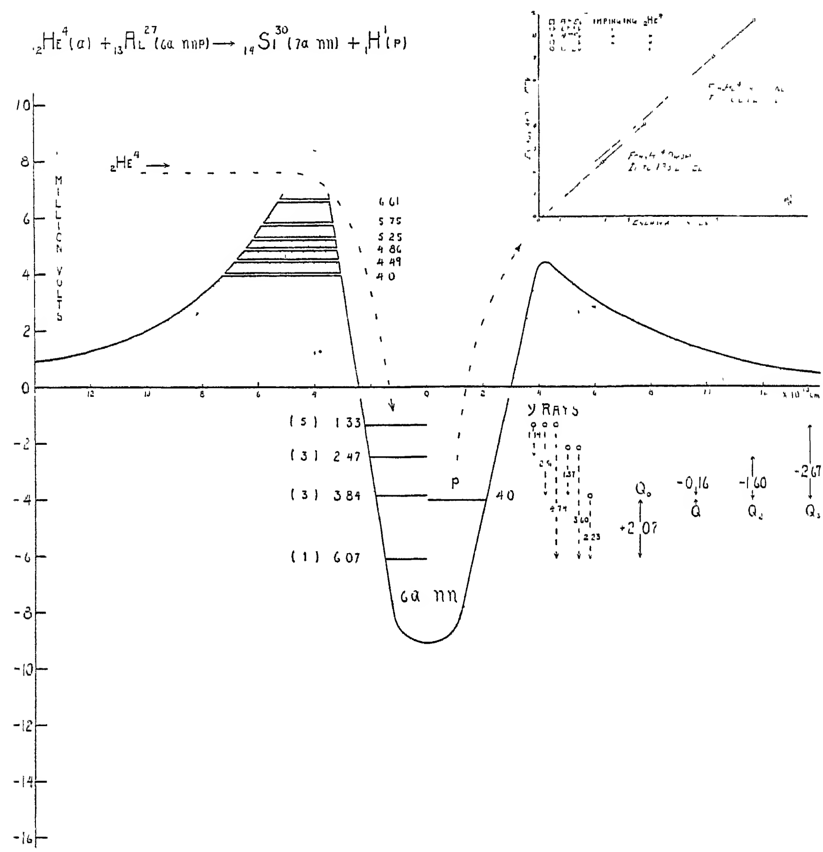

FIG. 6. Helium on Aluminum.

4.00336 + 10.0146 = 14.01796; after transmutation 13.0069 + 1.00807 = 14.01497. The decrease in mass is 0.00299. Using the Einstein mass-energy relation mentioned previously, this decrease in mass must now appear in the form of energy and in this case corresponds to 2.8 million volts of energy. This value is in only fair agreement with the observed energy gain of 3.1 million volts as shown by Q in the figure.

Only for alpha-particle bombardment does the potential barrier frequently exhibit a peculiar channeled structure. Through these channels (see also Fig. 6) the alpha particle

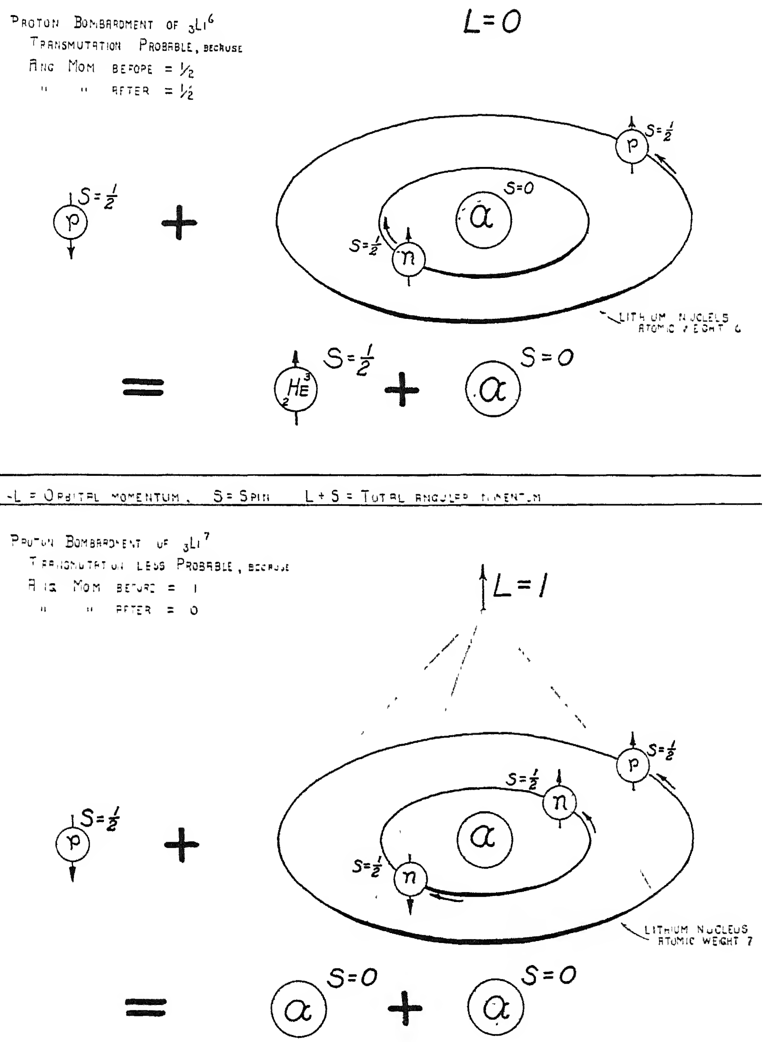

FIG. 7. Transmutation probabilities for protons on lithium 6, and on lithium 7.

seems to pass easily and the probability of a nuclear transmutation by alpha particles bombarding the nucleus with these particular energies is thereby greatly enhanced (11).

Fig. 2 shows the energy-level diagram (one of three) of an alpha particle itself and the large number of gamma rays observed (12). Notice how narrow and deep this nucleus is compared to the aluminum nucleus of Fig. 5.

NUCLEAR SPINS

So far we have used, although not explicitly expressed, three of the four conservation laws of nuclear physics. These laws are:

a). Conservation of electric charge.
b). Conservation of mass-energy.
c). Conservation of momentum.
d). Conservation of angular momentum.

The conservation of angular momentum is useful in explaining why some reactions are more probable than others (13). For example, consider Fig. 7 in which for proton bombardment the disintegration of lithium, atomic weight 6 (upper half of figure), is shown to be more probable than the disintegration of lithium, atomic weight 7 (lower half of figure). Assuming lithium, atomic weight 6, to consist of an alpha particle, a proton and neutron as shown, the total nuclear angular momentum is therefore $\frac{1}{2} + \frac{1}{2} = 1$. A proton with spin $\frac{1}{2}$ gives a resultant angular momentum before disintegration of $1 - \frac{1}{2} = \frac{1}{2}$, which is equal to the angular momentum after disintegration, $\frac{1}{2} + 0 = \frac{1}{2}$. This equality does not hold in the lower half of the figure, however, since before disintegration the total nuclear angular momentum is $(1 + \frac{1}{2} - \frac{1}{2} + \frac{1}{2}) - \frac{1}{2} = 1$ and after disintegration the angular momentum is $0 + 0 = 0$. The former reaction is about 30 times more probable than the latter. If sometimes, however, one of the alpha particles in the latter reaction is left in an excited state as indicated in Fig. 2, then the considerations just mentioned probably will not apply.

In closing, a word of caution should be said in regard to the tables and the figures presented here. They should not be read too closely or interpreted too literally because changes are being made from time to time in the data and in the interpretation of the data.

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DEUTERIUM AS A RESEARCH TOOL IN THE PHYSICAL AND BIOLOGICAL SCIENCES

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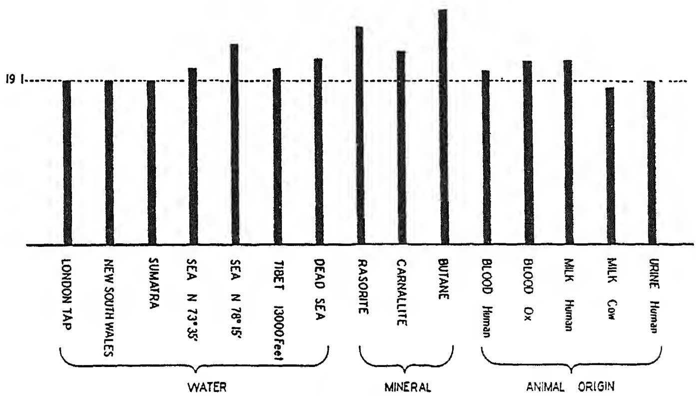
The discovery (1) of deuterium and the production of "heavy water," its chief compound, in a nearly pure state (2), are among the more important scientific achievements of recent years. In less than two years from the production of heavy water in nearly pure condition over three hundred papers reporting investigations *on* or *with* deuterium have appeared in scientific journals. While most of these investigations have been of a physical or chemical nature significant results have been reported in investigations of biological character. It is probable that the principal role of deuterium, in future research in all of these fields, will be more that of a research tool than as an object of investigation.

Deuterium is not a new chemical element, as the name might imply, but is a special variety of hydrogen atom. It differs from the ordinary (or light) hydrogen, chiefly, in mass. The atomic weight of the ordinary hydrogen is *one* while that of deuterium, or heavy hydrogen, is *two*. It resembles the ordinary hydrogen atom in possessing just one unit of positive charge on its nucleus (equal to the number of electrons in the neutral atom) and it is this latter property which determines the chemical character of an atom, and hence its position in the family of elements. The existence of atoms which differ in mass although alike in nuclear charge is common among the elements, and atomic species which are related in this manner are called isotopes. Isotopes are very difficult to separate, because they are so nearly identical in chemical behavior. Only with hydrogen in recent months have isotopic separations on a moderate scale been at all successful. The fact that this has been accomplished rather readily has made the special name, *deuterium*, advisable.

The chemistry of deuterium is, in the main, that of ordinary hydrogen. It is thus possible to have any of the hydrogen bearing compounds, so numerous in Chemistry, with one or more deuterium atoms replacing a corresponding number of ordinary hydrogen atoms. With water this leads to the two

possibilities HOD (D is the symbol which chemists employ to represent an atom of deuterium) and DOD. Pure "heavy water" consists of DOD alone, while heavy water of less than 100% purity consists of HOH, HOD, and DOD mixed in proportions which depend on the relative numbers of H and of D atoms in the mixture. In like manner three "heavy" ammonias—NH_2D, NHD_2 and ND_3—are possible and numerous deuterium derivatives of such molecules as benzene, C_6H_6; ethyl alcohol, C_2H_5OH; etc., can be produced.



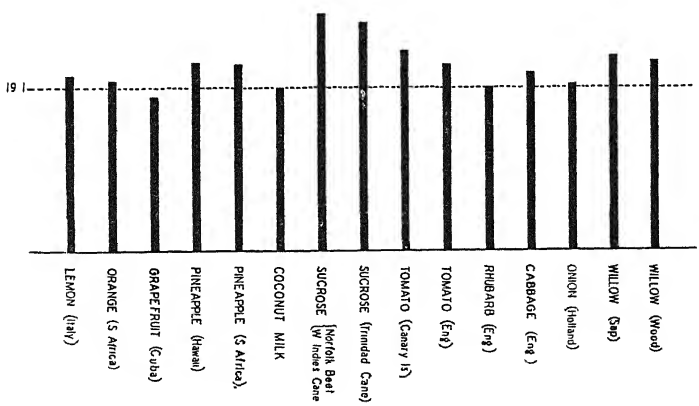


FIG. 1. (*Upper.*) Deuterium Content of Water from Natural Mineral and Animal Sources (relative to ordinary water).

FIG. 2. (*Lower.*) Deuterium Content of Water Obtained from Various Vegetable Sources (relative to ordinary water).

Replacement of light hydrogen in a molecule, by deuterium, necessarily results in an increase in the molecular weight—one unit for each replacement. Thus, for the respective molecules H_2O, HDO and D_2O molecular weights are 18, 19 and 20.

Molecular *volumes* are scarcely influenced by the replacements. As a result the *densities* of deuterium compounds are higher than for the corresponding compounds of ordinary hydrogen, and are in proportion to the molecular weights. The density of pure heavy water is very close to (20/18) times that of ordinary water and for less than 100% purity the density is a nearly linear function of the deuterium content. This provides one of the most convenient, as well as most accurate, ways of analyzing a sample of water for its deuterium content.

Deuterium exists in natural ground water to the extent of one D atom to about every 5800 H atoms (3) and contributes, through its presence, about 19.1×10^{-3} milligrams to the weight of each cubic centimeter of water. This proportion of D to H atoms is maintained, to a first approximation, in other natural sources but careful analyses reveal definite changes in the ratio which are characteristic of the nature of the source. The proportions of deuterium in waters derived from several mineral, vegetable and animal origins (4, 5, 6) is represented graphically in Figures 1 and 2 in which the dotted line (norm) corresponds to the deuterium content of normal ground water. Some of these variations in the ratio must be attributed to partial separations of the isotopes during chemical changes within living organisms—others to physical processes, such as evaporation.

The chemist does not *make* either deuterium or heavy water in the strict sense but is able to extract it from those natural sources—principally water—in which it already exists in low proportion. The high cost of heavy water is a consequence of the high cost of extraction and is not due to limitation of the gross supply. Indeed the potential supply of deuterium is inexhaustible. A simple calculation, based on the ratio of 1 D atom to every 5800 H atoms, reveals that enough deuterium is present in the circle of ocean visible from the deck of a large ocean liner to yield nearly one cubic mile of pure heavy water. By the cheapest process yet developed. the cost of extracting this quantity of D_2O would require a ten billion dollar annual expenditure for a period of 800,000 years. There is little doubt that the cost of extraction will continue to drop, as it has done rapidly during the past two years. In this period the cost of pure D_2O has dropped from $150 per gram to about $2.00 per gram.

Heavy water is ordinarily produced by a process of electrolysis. Figures 3, 4, and 5 are views of portions of the

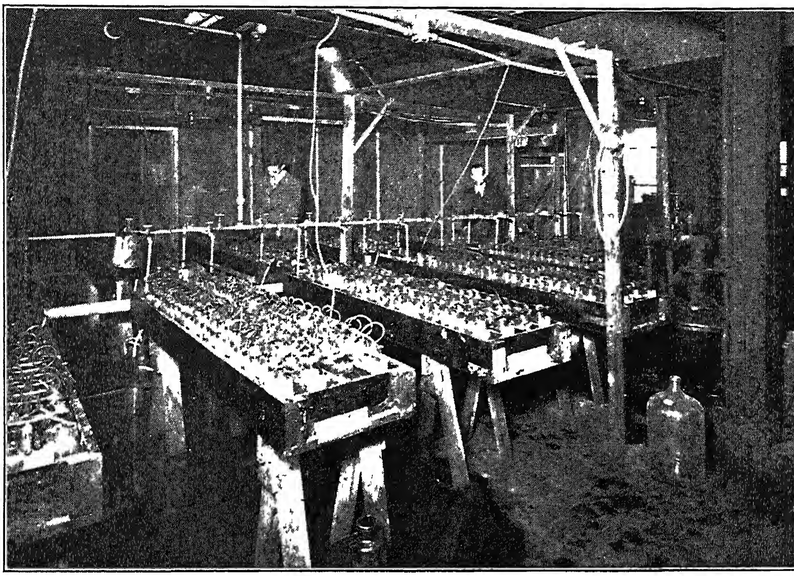
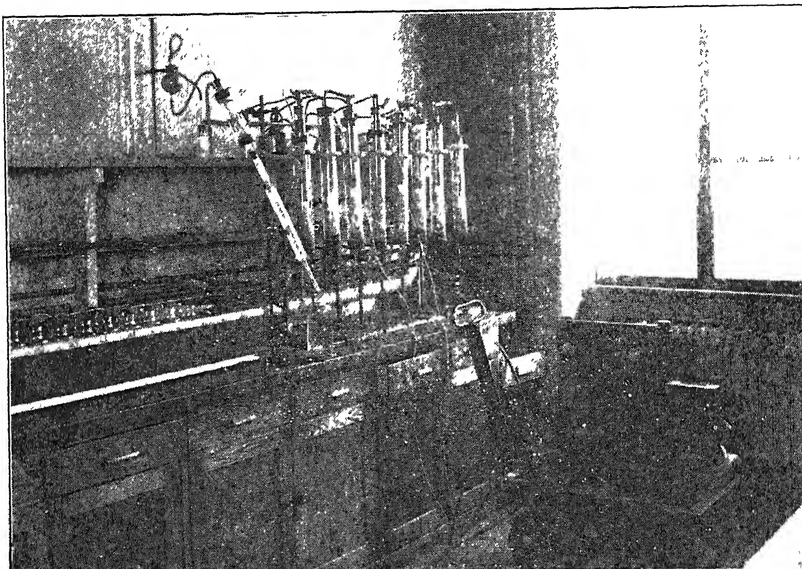


FIG. 3. Main Section of the Heavy Water Plant at the Ohio State University; 1000 water-cooled cells reduce 100 gallons of dilute heavy water from commercial cells, per week, to about 11 liters of 1% D_2O.



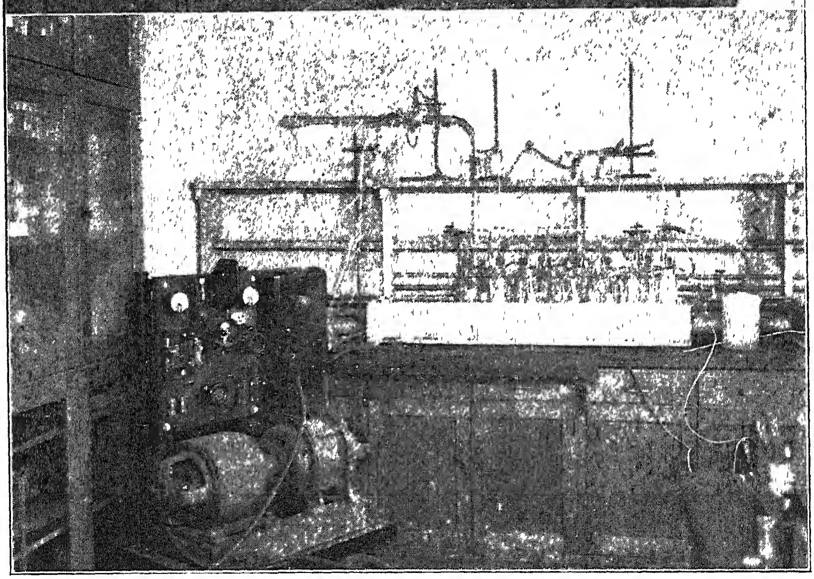


FIG. 4. (*Upper.*) Intermediate Section of the Heavy Water Plant at the Ohio State University. These cells of high current carrying capacity reduce the output of the Main Section to 10% D_2O. A burner and condenser for recombination of the electrolytic gases is shown in the foreground.

FIG. 5. (*Lower.*) Final Section of the Heavy Water Plant at the Ohio State University. These "test tube" cells reduce the output of the Intermediate Section to D_2O of concentration higher than 99%. The output is about 50 grams per week.

large heavy water plant constructed and operated at The Ohio State University,[1] which is capable of producing about fifty grams of pure D_2O per week at a cost of a little over $2.00 per gram. The use of the electrolytic process depends upon the fact that the H/D ratio in the hydrogen evolved in the electrolysis is 4 to 8 times larger than that in the electrolyte. As a consequence the concentration of deuterium in the residue increases as the electrolysis continues and approaches 100% as the volume of residue shrinks to zero. The efficiency of the process depends on the choice of electrodes and of electrolyte and on other conditions of operation.

Other methods may also be used to effect the extraction of deuterium. Distillation of water (7, 8) may in time replace the electrolytic process. Distillation of liquid hydrogen (1, 9) should be still more effective. Its principal hindrances are of an engineer-

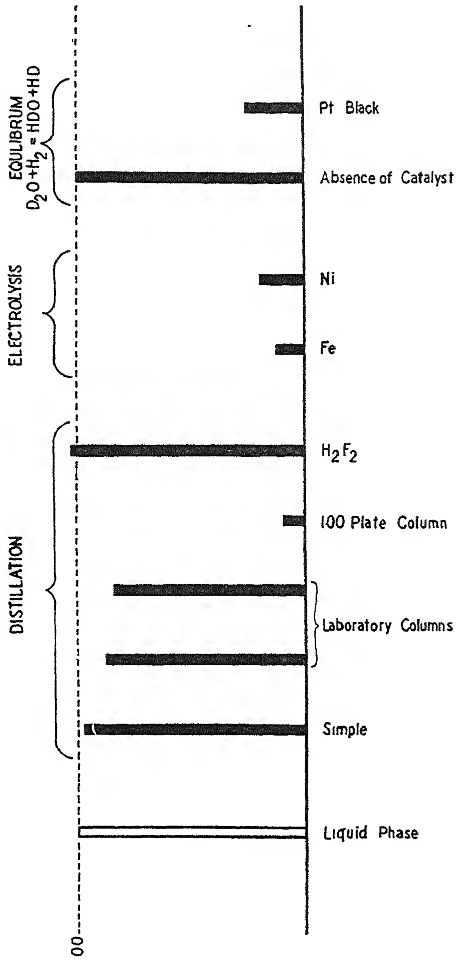


FIG. 6. Relative Efficiencies of Several Means of Separating Deuterium from the Lighter Isotope of Hydrogen. The heights of the vertical bars represent the deuterium content of the gas escaping from a liquid residue whose hydrogen is 1% deuterium.

[1]This plant was put into operation in March, 1934. The first and largest unit consists of approximately 1000 small water cooled cells constructed from ordinary 500 cc. wide-mouthed bottles closed with two-hole rubber stoppers and fitted with electrodes of Armco iron. The mixture of hydrogen and oxygen produced in the later stages of the electrolysis is allowed to recombine to reform water which is then electrolyzed over again, in an earlier stage of the plant, to recover the deuterium in the electrolytic gases. The raw material used in this plant was water taken from commercial electrolytic cells (D/H ratio, about 1/2000) and was furnished, free of charge, by the Capital City Products Co. of Columbus. The staff and students of the department of Chemical Engineering at

ing character and can, no doubt, be overcome. Diffusion (10) and desorption (11) processes and chemical reactions (12, 13) that liberate hydrogen or its gaseous compounds represent yet other ways of separating deuterium from its more plentiful isotope. Relative efficiencies of a number of these methods are

TABLE I

COMPARISON OF SOME PROPERTIES OF NORMAL WATER WITH THOSE OF PURE HEAVY WATER (COLLECTED FROM VARIOUS SOURCES)

	H_2O	D_2O
Molecular Weight	18	20
Specific Gravity	1.0000	1.1079
Freezing Point	0° C.	3 80
Boiling Point	100° C.	101 42
Refractive Index	1 33300	1 32828
Dielectric Constant	81.5	80.7
Viscosity (30°)	8 00	9 72
Heat of Fusion	1435	1510
Heat of Vaporization	10484	10743
Ionization Constant	1×10^{-14}	0.3×10^{-14}

Vapor Pressure Ratio (pH_2O/pD_2O) $\approx$ 1.05 at 100° C.
Solvent Action Toward Salts—Solubility in D_2O 80% to 90% of that in H_2O.

TABLE II

COMPARISON OF SOME PROPERTIES OF MOLECULAR HYDROGEN WITH THOSE OF PURE DEUTERIUM (COLLECTED FROM VARIOUS SOURCES)

	H_2	D_2
Molecular Weight	2.0156	4 027
Freezing Point	13.92° K.	18.58° K.
Boiling Point	20.38° K.	23.5° K.
Heat of Fusion	28 0 cal/mole	47.0 cal/mole
Heat of Vaporization	217.7 cal/mole	308.3 cal/mole
Heat of Dissociation (into atoms)	102,800 cal/mole	104,425 cal/mole
Viscosity (gas at 30° C.)	916 c. g. s. units	129 5

illustrated in Figure 6. Indeed, it is difficult to find a process —physical or chemical—in which measurable change in the proportion of the hydrogen isotopes is not produced.

The Ohio State University assisted in the preliminary preparations by distilling the water out of the strong alkaline electrolyte which was used in the commercial cells, and preparing fresh electrolyte for return to the Capital City Products Co. Dr. J. H. Koffolt was in immediate charge of this operation. The construction and operation of the heavy water plant was carried out with the assistance of Mr. W. H. Hall, graduate student in the Department of Chemistry.

Table I is a comparison of a few of the properties of pure D_2O with those of H_2O.

Table II is a similar comparison of molecular hydrogen with molecular deuterium, and Figure 7 illustrates the heat capacity vs. temperature curves (14) of the respective molecules H_2, HD and D_2. Other compounds of hydrogen would exhibit similar variation in properties from those of their deuterium analogues. In general the differences in properties are greatest at low temperatures.

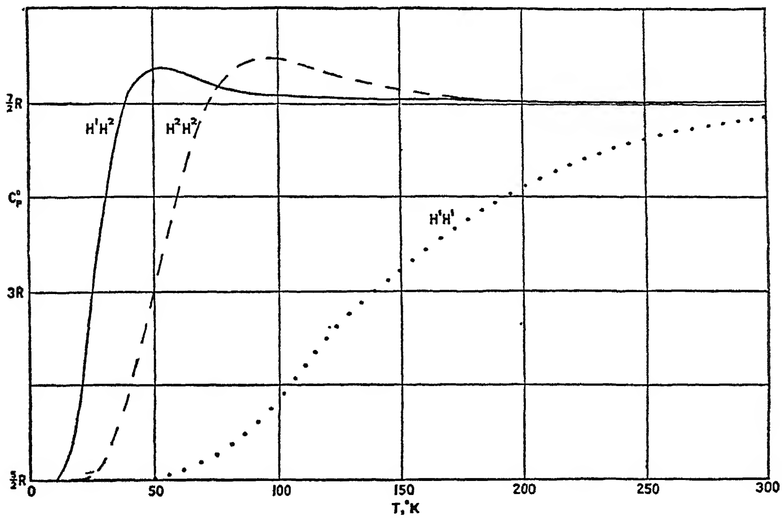


FIG. 7. Heat Capacity Curves (non equilibrium mixtures with respect to ortho-para states of D_2 and H_2) of H_2, HD and D_2. (After Johnston and Long, J. Chem. Physics **2,** 389 [1934].)

The utility of deuterium in research depends, in the majority of cases, directly or indirectly on variations such as are exhibited in Tables I and II or on quantitative estimates of the presence of deuterium, which utilize certain of these properties. Measurements of specific gravity (21, 15) or of refractive index (15, 16, 17) of carefully purified samples of water constitute the more usual and more accurate means of analyzing for deuterium but the measurement of the thermal conductivity (18) of gaseous mixtures of hydrogen and deuterium is not infrequently employed. The latter method is based on the differences in specific heat (Figure 7) on which thermal conductivity is dependent, and possesses the advantage that very tiny amounts of gas may be analyzed by this method.

It is possible, in this address, to illustrate the use of deuterium as a tool in solving fundamental problems in scattered fields for only a few of the cases in which it has been so employed. But these can be chosen to illustrate its wide range of applicability. For convenience I shall discuss these under the several headings of Physics, Chemistry, and the Biological Sciences.

PHYSICS

Modern Physics is concerned primarily with the structure of matter. This includes both the atom and the molecule and, more recently, attention has been turned to the tiny and almost inaccessible nucleus of the atom. Great progress has been made in nuclear investigations since the discovery of deuterium and the use of the deuteron, its own nucleus, to bombard the nuclei of heavier atoms or to produce *neutron* beams (19) of high intensity for the bombarding projectiles. This has resulted, in the brief space of two years, in the production of new radioactive substances (20) which possess utility as radioactive indicators in various types of chemical investigations and are sufficiently active to compete with natural radioactive elements in the treatment of disease. Continued progress in this field of nuclear investigation—with deuterium an indispensable tool—must inevitably result in a nuclear chemistry of far-reaching consequences and may unlock vast new storehouses of energy.

The greatest impetus to modern physical research came in Bohr's well known theory of the hydrogen atom. Although this theory broke down, in its details, when applied to the heavier elements it yielded, with Sommerfeld's modification, good quantitative agreement with all experimental observations of hydrogen itself. This theory of Bohr predicts very definitely the positions of lines in the spectrum of atomic deuterium. These lines should appear slightly shifted from the corresponding lines of ordinary hydrogen and the amount of the shift is calculable in terms of the theory. It is therefore of considerable interest that the discovery (1) of deuterium was based on the presence of weak lines at the positions calculated for an hydrogen atom of mass two (cf. Figure 8) and that further research (2) with much richer mixtures of deuterium and with higher dispersion in the optical systems (cf. Figure 9) were in good accord with the quantitative aspects of the simple Bohr theory. One

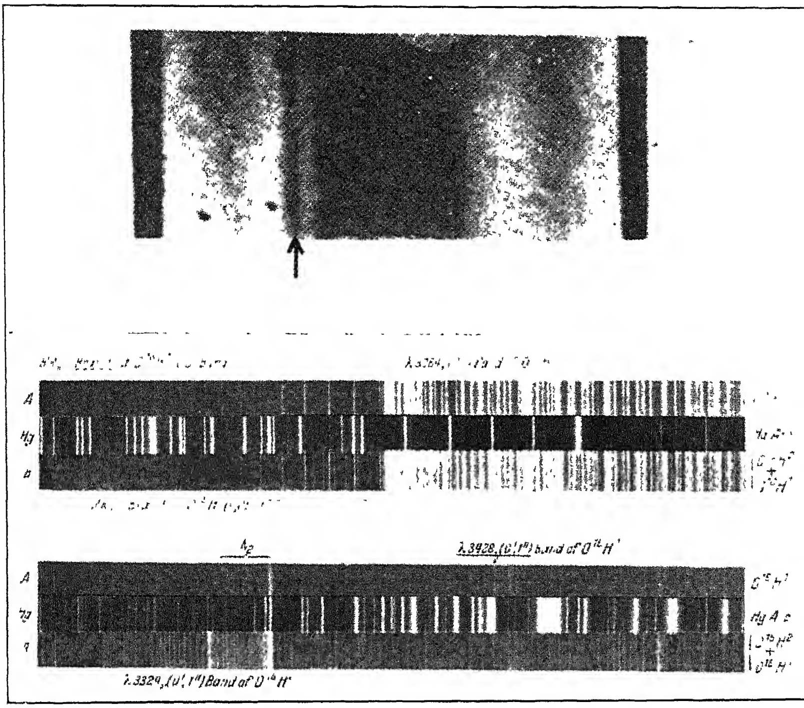


FIG. 8. (*Upper.*) Isotope Shift in one of the Balmer lines of Hydrogen (after Urey, Brickwedde and Murphy, Phys. Rev. **40,** 1 [1932]). The narrow line above the arrow is due to the D atom in hydrogen gas enriched slightly in deuterium by evaporation of liquid hydrogen.

FIG. 10. (*Lower.*) Isotope Effect in the Spectrum of OH (after Johnston and Dawson, Naturwissenschaften **21,** 495 [1933]). (The center strips in each panel are spectra of the mercury arc used for reference.)

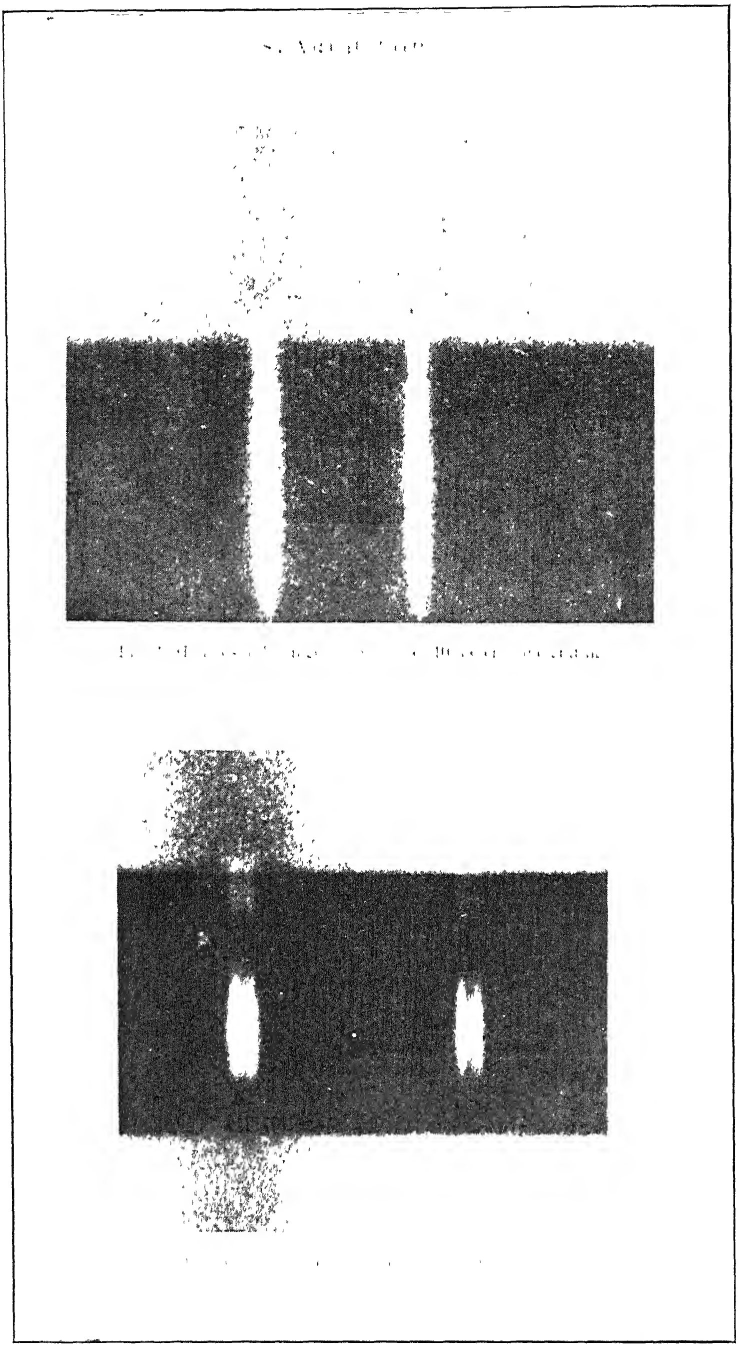


FIG. 9. Wider Separation of the Isotope Lines due to atomic hydrogen with a nearly 50–50 mixture of H_2 and D_2. (After G. N Lewis and F H. Spedding, Phys. Rev. **43**, 964 [1933].) Note the sharper resolution of the doublet lines for one of the doublets on the lower photograph. This is the D line (these "lines" are really multiple) and is better resolved because of the smaller Doppler effect for the heavier atom.

quantitative feature of Sommerfeld's modified form of the Bohr theory, which involves the resolution of apparent single lines into several "fine structure" components, could never be tested adequately for ordinary hydrogen—due to overlapping and blurring of the component lines caused by the high velocity of hydrogen atoms moving in the region of the exciting discharge (Doppler effect). Simple gas kinetic theory indicates that the atomic velocities, and hence the blurring, should be less with deuterium than with hydrogen, so that this quantitative aspect of the Bohr-Sommerfeld-spin theory might now be subject to test. This is found to be true and investigations (22, 23) which may prove of considerable help in unravelling difficult aspects of atomic structure theory are in progress.

The structure of the molecule and the nature and magnitude of the binding forces which hold atoms together in individual molecules is a realm of great interest to chemists as well as to physicists. A great deal of progress has been made in this field during the past decade but there are still many problems unsolved even for the case of comparatively simple diatomic molecules. Knowledge in this field has come mainly through the study and interpretation of molecular spectra, commonly referred to as "band spectra," due to their characteristic appearance at low dispersion.

Errors in interpretation have arisen, not infrequently in the past, through failure to correctly identify the chemical nature of the molecule responsible for a spectrum. When it is possible to replace one atom in the responsible molecule by its isotope every line in its spectrum is shifted and the shifts on individual lines are calculable by theory. The use of this so-called isotope effect can therefore be employed sometimes to identify the chemical nature of the molecule responsible for a spectrum since the theoretical calculation of the shift depends on the correct chemical identification. An example of this kind (24) is illustrated in Figure 10. The spectra reproduced in this figure are emitted by water vapor through which an electrical discharge of high potential is passing and were variously assigned, in the early years of study, to the H_2O molecule and to the O_2 molecule. It was later interpreted as due to the unfamiliar gaseous molecule OH and these photographs obtained by passing an electrical discharge through a mixture of ordinary and heavy water definitely confirms this latter assignment. The RR lines whose positions are indicated on the bottom of

the (0, 0) band photograph and the λ 3329 band on the lower photograph fall very close to the positions calculated for an OD molecule. In this particular case the chemical identity of the molecule responsible for the water vapor spectrum was satisfactorily established beforehand but in the case of other molecules containing hydrogen—particularly molecules with more than two atoms—the isotope shift, with deuterium substitution, provides a means both of molecular identification and of the correct assignment of vibrational quantum numbers. Clues to the explanation of difficult points in the theoretical interpretation of complex molecular spectra and of the correct calculation of inner forces are also provided by exact quantitative measurement of the large isotope shifts in deuterium compounds and their departure from simple theory.

CHEMISTRY

Chemically, deuterium resembles ordinary hydrogen. However, this resemblance is not complete and small differences are found in equilibrium constants and, in several instances, rather large differences in reaction velocities. Perhaps the most important change in an equilibrium constant is that of the ionization constant of water to yield hydrogen and hydroxyl ions. For pure heavy water this important constant is about one-third (cf. Table I) of that for ordinary water, which indicates that the degree of ionization of D_2O is only 60% of that of H_2O. In a like manner weak acids or bases dissolved in D_2O ionize to a lesser degree (25) than in H_2O. The effect of these changes in important ionic equilibria is to change pH values and otherwise modify the character of certain ionic reactions in solution. Equilibrium changes of this character no doubt contribute to the biological effects of heavy water. A number of gas and gas-liquid phase equilibria whose constants show the isotopic influence on the reactivity have also been investigated, (26, 27, 28, 29, 14).

An interesting and important example of a chemical difference between deuterium and hydrogen compounds is furnished in displacement reactions of metals with water or with acid to yield gaseous hydrogen and in similar reactions which liberate gaseous compounds of hydrogen. The first examples of this sort were reported by A. and L. Farkas (12) and by Davis and Johnston (13) who observed, independently, that the gas liberated in reactions of this character, from solutions

which were a mixture of H_2O and D_2O, contained a lower proportion of deuterium than the solution from which it was liberated. The deuterium impoverishment in the gas stream is sometimes quite marked. The extent of this impoverishment is highly reproducible and is almost independent of the nature of the solution but is dependent on the surface character of the reacting metal. Figure 11 (30) illustrates the extent of this impoverishment for several reactions of this character. To what extent this effect may be attributed to changes in equilibrium constants and to what extent to differences in the reaction velocity of the heavy and light molecules or ions in the mixture is not yet known.

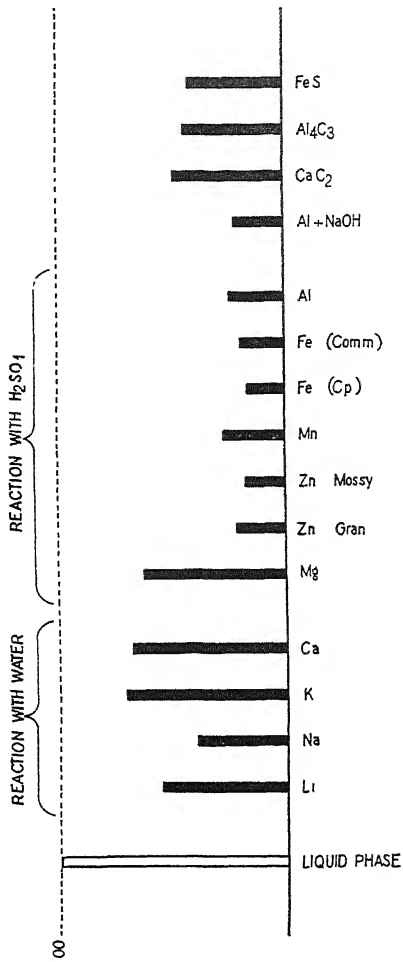


FIG. 11. Efficiency of several chemical replacement reactions in the separation of the hydrogen isotopes. The heights of the bars represent the deuterium contents of gas escaping from a liquid residue whose hydrogen is 1% deuterium. (Unpublished work of H. L. Johnston and C O. Davis.)

A very simple type of reaction with isotopic atoms which is of great service in indicating the tightness of binding of various linkages and in studying chemical kinetics is of the type known as an "exchange" reaction. This type of reaction was first observed by Lewis (31) who observed that the hydrogen atoms in ammonia gas which was bubbled through a dilute heavy water solution "exchanged" with the hydrogen and deuterium atoms in the water (evidenced by the deuterium atom exchange) so that the deuterium concentration of the escaping ammonia approached that of the residual water. The mechanism of this exchange is represented by the following reaction:

$$NH_3 + HDO = NH_2D + H_2O \tag{1}$$

which probably goes through the steps

$$NH_3 + HDO \rightleftarrows NH_3DOH \rightleftarrows NH_2D + H_2O \quad (\text{or } NH_3 + HDO)$$
$$\text{or} \rightleftarrows NH_4OD \rightleftarrows NH_3 + HDO. \tag{1a}$$

With water containing a high concentration of deuterium, reaction of NH_2D may continue by a mechanism corresponding to (1a) until two or, finally, all three of the hydrogens of the original amomnia are exchanged with deuterium in the water. Likewise all four hydrogens in ammonium ion (NH_4^+) (32) and the acid hydrogen in strong acids (33) exhibit rapid exchange with water.

Interesting examples of exchange reactions between water and hydrogen of various linkages in organic compounds are shown in Table III, which is taken from the extensive review article of Urey and Teal (34).

TABLE III

EXCHANGE REACTIONS BETWEEN WATER AND ORGANIC COMPOUNDS

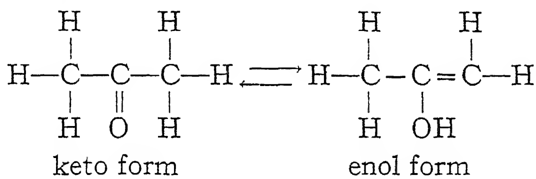
Compound	Observation	Reference
CH_3COONa	No exchange	(35)
CH_3COOH	1 hydrogen atom exchanges rapidly	(36)
C_6H_6	No exchange	(35)
CH_3CHO	1 hydrogen atom exchanges slowly	(35)
CH_2O	2 hydrogen atoms exchange slowly	(35)
CH_3COCH_3	Very slow exchange in neutral solution. Faster exchange in acid solution. Very fast exchange of all hydrogens in alkaline solution	(35, 37, 38)
$CH_3COCH_2COCH_3$	All hydrogens exchange	(35)
C_2H_2	Exchange in alkaline solution	(39)
Glucose and cane sugar	Hydroxyl hydrogen exchange immediately	(32)
$(CH_2OH)_2$	One-third of hydrogens exchange immediately	(33)
Egg Albumen	All hydrogens attached to N. atoms exchange.	(40)
Cellulose	All hydroxyl hydrogens exchange	(40)

The several investigations included in this table show the immobility of hydrogen attached directly to carbon except where keto-enol transformations are possible; the high mobility of carboxyl, hydroxyl and amino hydrogen and the low mobility of aldehydo hydrogen. The exchange with acetylene in alkaline solution provides evidence for the weak acidic character of

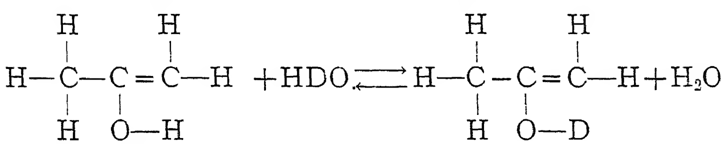
acetylene in aqueous solution, for which there was some evidence from other sources. This probably results from an equilibrium of the type.

$$C_2H_2 \rightleftharpoons C_2H^- + H^+ \qquad (2)$$

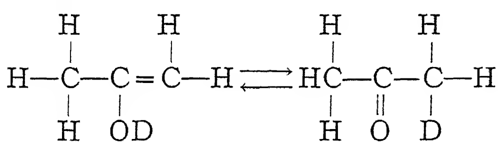
The exchange in acetone, in contrast to the resistance to exchange by methyl hydrogen in acetates and in acetic acid, is evidence in favor of the keto-enol transformation in acetone—a question which has been in dispute on the basis of direct chemical evidence alone. The exchange probably occurs with the hydroxyl hydrogen of the enolic form of the molecule and follows the following set of reactions.



(3a)



(3b)



(3c)

This process may be repeated, in water of high deuterium content, until all six hydrogens of the acetone are replaced by deuterium.

A good example of the application of deuterium exchange reaction to problems of molecular structure is illustrated by the oxygen acids of phosphorus. Complete exchange of the three hydrogens in ortho phosphoric acid, H_3PO_4, takes place in line with the chemical expectation of complete hydrogen replacement to form the normal salts (e. g., Na_3PO_4) and illustrates that all three hydrogens in this molecule are attached by a mobile type of linkage. Two of the three hydrogens exchange in ortho-phosphorus acid (H_3PO_3) and only one of the three in hypo-phosphorus acid (H_3PO_2) (33). The immobility of a portion of the hydrogen in the latter acids points to a different type of linkage for the immobile atoms than that prevalent in

H_3PO_4. The structure of the latter molecule is characteristic of strong oxygen acids, such as sulphuric, and involves hydrogen linked to phosphorus, *through oxygen*. There are apparently only two such linkages in the H_3PO_3 molecule and only one such linkage in H_3PO_2. The probable structures of the three molecules based on the exchange phenomena is represented below.

$$\begin{array}{ccccccccc} &&&& H &&&& \\ &&&& \cdot\cdot &&&& \\ &&&& O &&&& \\ &&&& \cdot\cdot &&&& \\ H & : & O & : & P & : & O & : & H \\ &&&& \cdot\cdot &&&& \\ &&&& O &&&& \end{array} \qquad \begin{array}{ccccccccc} &&&& H &&&& \\ &&&& \cdot\cdot &&&& \\ H & : & O & : & P & : & O & : & H \\ &&&& \cdot\cdot &&&& \\ &&&& O &&&& \end{array} \qquad \begin{array}{ccccccc} && H &&&& \\ && \cdot\cdot &&&& \\ O & : & P & : & O & : & H \\ && \cdot\cdot &&&& \\ && H &&&& \end{array}$$

$$H_3PO_4 \qquad\qquad\qquad H_3PO_3 \qquad\qquad\qquad H_3PO_2$$

The dots represent the position of bonding electrons which hold the atoms together. The immobile hydrogens are linked directly to phosphorus in a manner analogous to the immobile linkage direct to carbon in organic molecules. Latimer and Rodebush have previously postulated these structures for H_3PO_3 and H_3PO_2 on the basis of direct chemical evidence.

The most important results obtained through the use of deuterium in chemical research have been through its use as a tracer in chemical processes. The introduction of deuterium into a molecule provides a way of "labelling" the molecule which does not appreciably alter its normal chemical behavior. If deuterium be introduced at a definite position in an organic molecule the *normal* behavior of an hydrogen atom attached at that position, or of the group of which it is a constituent, during a chemical reaction, may be determined by tracing the deuterium through the products of the reaction. One excellent example of this use is in connection with determination of the mechanism by which ammonia decomposes in ultraviolet light. Stoichiometrically, the reaction is

$$2\,NH_3 + \text{ultraviolet light} = N_2 + 3H_2 \tag{4}$$

and the first step is thought to be

$$NH_3 + \text{light} = NH_2 + H \tag{4a}$$

The principal objection to this proposed mechanism is that only one-fourth as much NH_3 is decomposed for a given light absorption as is to be expected if this is the mechanism. This objection is over-ruled if it can be shown that the reverse

$$NH_2 + H = NH_3 \qquad (4b)$$

reaction can occur spontaneously. Taylor and Jungers (41) have demonstrated, with the aid of deuterium that reaction (4b) does take place. They accomplished this by introducing deuterium atoms (produced by impacts of suitably energized mercury atoms on D_2 molecules) into dry ammonia gas and observing, by means of the spectrograph, the presence of NH_2D, of NHD_2 and of ND_3 molecules in the gaseous mixture. In the absence of direct exchange (no exchange occurs between dry NH_3 and D_2 in the absence of a catalyst) reaction (4b) is the only apparent mechanism which can account for the introduction of the deuterium. (The introduction of more than one atom of deuterium must have come about through repetition of reaction (4a) on ammonia molecules into which deuterium was already introduced by reaction (4b).

An unexpected reaction between ethylene and hydrogen, which is no doubt typical of other organic molecules with one or more double bonds, has been observed by Farkas, Farkas and Rideal (42) through a study of the reaction between ethylene and deuterium on the surface of a nickel wire. These authors find that both reactions

$$C_2H_4 + D_2 = C_2H_4D_2 \qquad (5)$$

and

$$C_2H_4 + D_2 = C_2H_2D_2 + H_2 \qquad (6)$$

occur simultaneously and by independent processes. Reaction (5) is the analogue of direct hydrogenation of the unsaturated molecule and is expected. Reaction (6), which predominates at temperatures above 60°C, represents a loosening of the C-H bond at the catalyst surface. This loosening, with exchange of atoms between the ethylene and hydrogen molecules undoubtedly occurs in mixtures of double bonded compounds with ordinary hydrogenation but is revealed, for the first time, through the deuterium tracer. An exchange of similar character between deuterium and the hydrogen in saturated aliphatic molecules does not occur at low temperatures but, through the tracer action of deuterium, Taylor and coworkers (43) have recently found evidence for exchange between methane CH_4, and deuterium at 170° C, on a nickel catalyst. The significance of this discovery is that it provides evidence for the breakdown of methane into the fragments CH_3 and H on a nickel catalyst at a temperature two hundred degrees lower than it has been possible to detect it by other means.

A particularly important result, from a practical standpoint has come about through a study of the exchange reaction

$$H_2 + D_2 = 2HD \tag{7}$$

This reaction does not occur at all at moderate temperatures in the absence of catalysts. But in the presence of certain catalysts which are effective in commercial hydrogenation processes Gould, Bleakney and Taylor (44) find that the reaction takes place at temperatures even as low as that of liquid air. This reaction can only take place through the formation of atoms on the catalyst surface and the probable mechanism by which this occurs is illustrated in Figure 12.

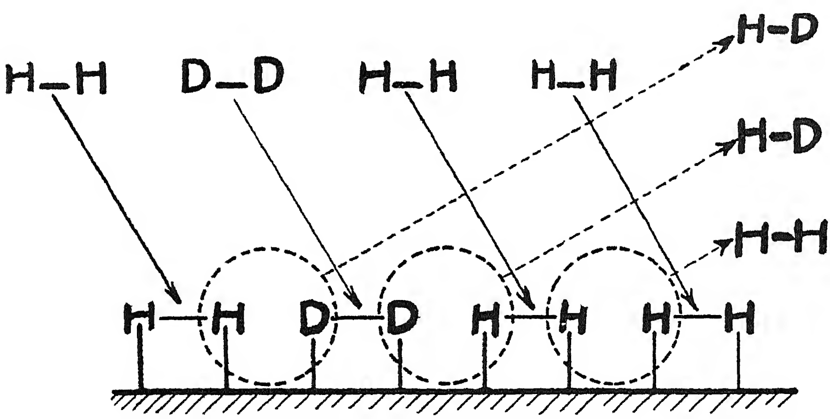


FIG. 12. Illustration of the probable manner in which the molecular bonds in H_2 and in D_2 are weakened on the surface of an hydrogenation catalyst so as to permit the re-pairing of atoms (or other rebonding of hydrogen atoms).

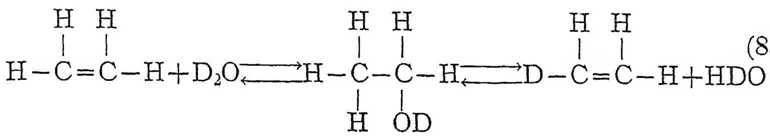
The figure is intended to show the way in which bonds established between the catalyst and the separate atoms weaken the bonds of atom to atom and permit return to the gas phase with an exchange of partners. This process—the loosening of hydrogen molecular bonds—is essential in many important industrial hydrogenation processes—such as the synthesis of ammonia from its elements. The experiments with deuterium show that the slow rate at which these commercial processes occur even at elevated temperatures is due to causes other than the loosening of the hydrogen bond, to which the slow reaction was previously attributed, and point the direction of future research.

The exchange reactions:

$$C_2H_4 + 2D_2O \rightleftarrows C_2D_4 + 2H_2O \tag{8}$$

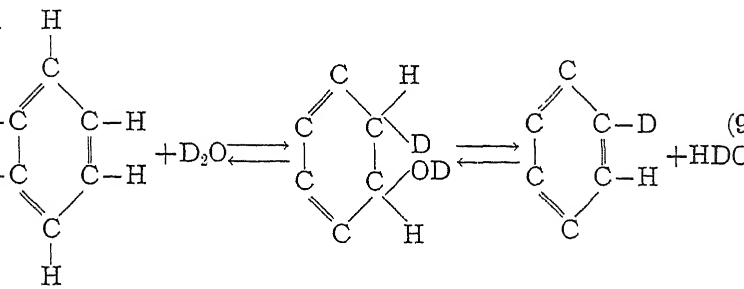
$$C_6H_6 + 3D_2O \rightleftarrows C_6D_6 + 3H_2O \tag{9}$$

with liquid water occur only in the presence of sulfuric acid (45, 46). Polanyi (46) seeks to account for the influence of the acid by the mechanisms:



(8a)

and



(9a)

This proposal is the introduction of a water molecule into a double bond, in either case, and is the opposite of a dehydration process, for which sulfuric acid is very effective. Polanyi bases his proposal on the fact that a true catalyst promotes approach to an equilibrium condition from either direction. Further research will be necessary in this case to establish the true nature of the catalytic action of sulfuric acid but the possibility of some very interesting results in our understanding of the mechanism of catalysis is apparent.

Reaction velocities in processes which involve deuterium or its compounds generally differ from the velocities of the corresponding reactions with ordinary hydrogen. As a rule the effect of deuterium is to slow down the reaction. Figure 13 (47) illustrates this for the reaction of aluminum with sulfuric acid. In the case of certain of the simpler gaseous reactions it has been possible to correlate the velocity change, quantitatively, with the mechanism of the reaction. Thus for the reaction

$$H_2 + Br_2 = 2HBr \tag{10}$$

Bonhoeffer, Bach and Fajans (48) find that D_2 reacts five times more slowly than H_2 at 283° C. This is in good agreement with the 1600 calorie higher energy (Table II) required to dissociate D_2 for step (b) of the proposed mechanism

$$Br_2 = 2Br \tag{10a}$$

$$Br + H_2 = HBr + H \tag{10b}$$

$$H + Br_2 = HBr + Br \tag{10c}$$

$$2Br = Br_2 \tag{10d}$$

in which (10b) and (10c) constitute a "chain" broken by (10d), and (10b) is the rate controlling step in the mechanism. Melville (49) finds that the slower reaction rates of deuterium,

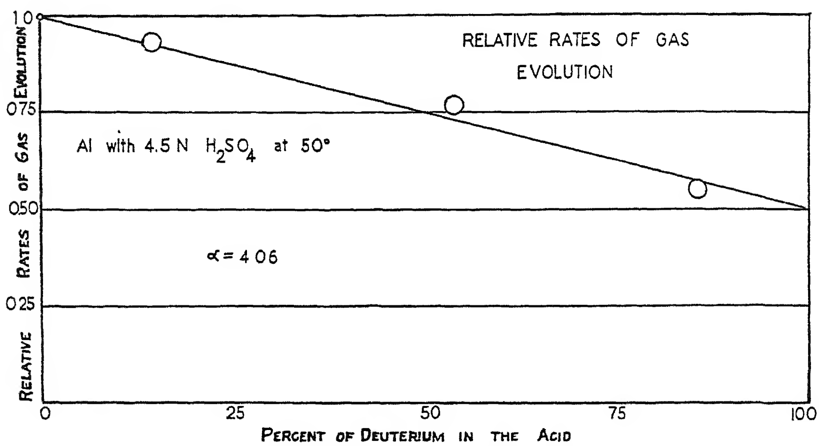


FIG. 13. Influence of Deuterium on the rate of reaction between Zinc and Sulfuric Acid. (Unpublished work of H. L. Johnston).

than of hydrogen, toward both O_2 and N_2O at the surface of a nickel catalyst are likewise in quantitative agreement with the difference in energies required to bind D and H atoms, respectively, to the catalyst surface.

A few examples have been found in which reaction rates with deuterium compounds proceed more rapidly than with ordinary hydrogen compounds (50, 51).

The use of deuterium as a tool in organic structural chemistry and mechanism—in which it should prove useful both as a tracer and as an indicator of the presence of groups which contain mobile hydrogen—is, as yet, scarcely touched.

BIOLOGY

Water with a high content of deuterium possesses a direct influence on certain physiological processes. Lewis (52) found that tobacco seeds fail to germinate in 80% heavy water (an excellent illustration of the results of this experiment, together with the 100% germination shown by controls, is given in the reference) and that the action of the heavy water is to inhibit or retard germination rather than to render the seed sterile (53). A similar inhibitory effect was observed for lupino seeds in dilute heavy water (54) but no effect whatever was observed on the germination of wheat (55). Taylor and his associates (56) have shown that high concentration of D_2O are fatal to tadpoles and to guppies within a few minutes and to lower organisms such as flatworms and protozoa within a few hours. Experiments of this sort have been frequently repeated by Taylor (57) with care exercised to eliminate every extraneous cause of the lethal action and the results reported in the original paper have been, each time, confirmed. Internal administration of nearly pure heavy water to a mouse (53), while not lethal in effect, did produce decided physiological reaction. This consisted of an increase in thirst and in a high excitability resembling intoxication.

The manner in which water with a high deuterium content is responsible for physiological changes is not known although there are several possibilities in view of the modifications of physical and chemical properties of water itself. These include: the change in the ionization constant of water and in the ionization and hydrolysis constants of dissolved electrolytes; unequal changes in the rate constants of various interdependent biochemical reactions taking place in the organism; the hydroscopic action of heavy water (i. e., its ability to absorb ordinary water from or through the tissues much as absolute alcohol would do) and changes in osmotic pressure. These possible causes of physiological modification are in addition to direct toxic effect of deuterium compounds themselves. It is unknown whether or not a direct toxic effect exists.

In addition to these investigations with whole organisms some significant results have been obtained in experiments on the metabolism of special cells in the presence of water having a high deuterium content. Drs. Doan, Wiseman and associates in Ohio State's Department of Medical Research (58) have made a quantitative study of the influence of both 7% and 50%

heavy water on the metabolism of white blood corpuscles, by means of a Warburg apparatus. They find marked decreases in the rate of respiration in the presence of heavy water, with the effect much greater for the 50% heavy water, although no effect was produced either on the rate of CO_2 metabolism or on

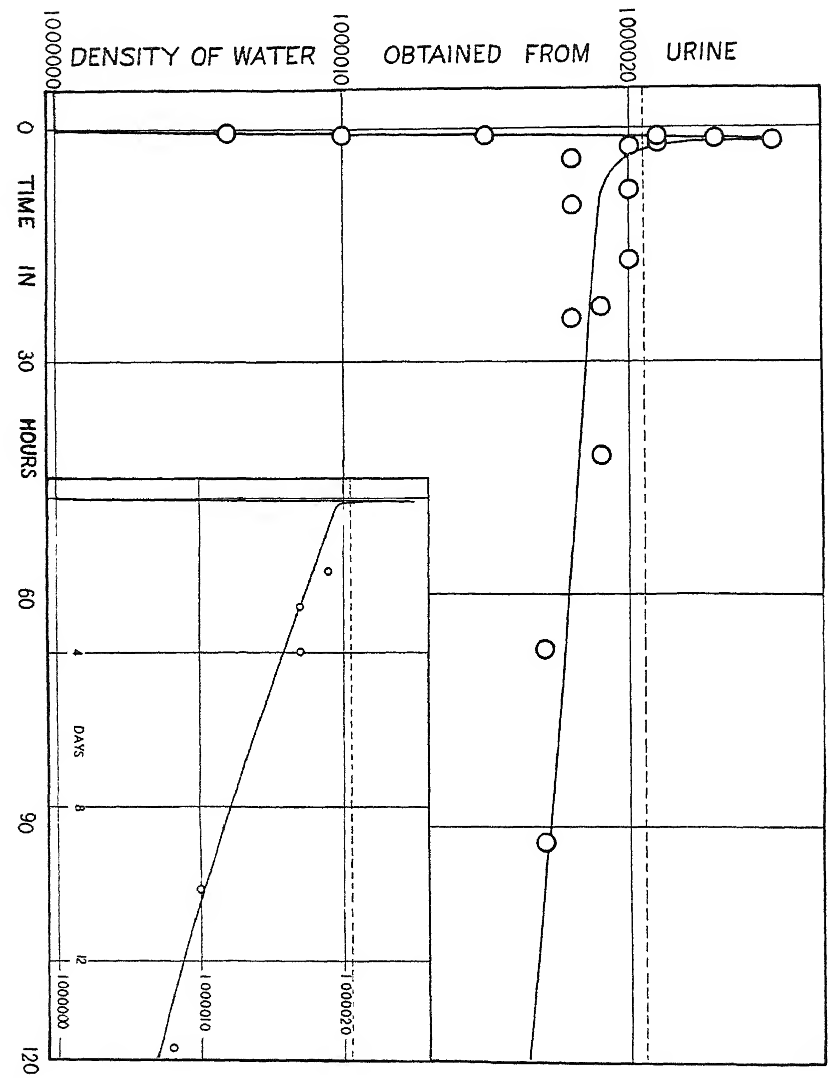


FIG. 14. Loss of Deuterium with urine following drinking of dilute heavy water. (Constructed from the data of Hevesy and Hofer.) The dotted line represents the specific gravity to be expected for water from a fluid produced by mixing two liters of 0.5% D_2O with 45 liters of ordinary water.

glycollosis. This result is interesting because natural causes which modify the respiration rate also modify CO_2 metabolism and glycollosis and the magnitudes of the several effects are usually related. Investigators at Princeton have also made extensive studies of the influence of D_2O on cell respiration and obtained smooth curves which relate the rate of respiration to the deuterium content of the water (59).

Pacsu (60) finds that the alcoholic fermentation of d-glucose in 95% heavy water proceeds nine times more slowly than in ordinary water, and in 60% heavy water with about two-thirds of the velocity in ordinary water. The fact that yeast which has first been cultured in 95% D_2O fails to regain activity when the culture solution is diluted to 45% D_2O shows that deuterium here exerts a permanent toxicity toward the zymase enzyme.

The tracer action of deuterium may be utilized in biological, as in chemical, research and it is probably safe to predict that this use in biological investigations opens a wider field for its utilization than the study of its direct physiological effects. An excellent example of this utilization is contained in the recent very interesting work of Hevesy and Hofer (61) who used deuterium to find how rapidly water taken internally becomes distributed through the human body. The experiment consisted in carrying out systematic deuterium analyses of the urine excreted by a person who drank two liters of water about 0.5% of whose hydrogen was deuterium. Figure 14 shows the results of the experiment. The ordinates measure the specific gravity of the water distilled from the urine. The abscissa represents the duration of the investigation. The two liters of 0.5% D_2O was taken at time zero. Analysis of the urine preliminary to the start of the investigation yielded normal water (cf. Fig. 2). The dotted line in the figure represents the specific gravity to be expected if the two liters of 0.5% heavy water were thoroughly mixed with the approximate 45 liters (two-thirds of body weight) of water present in the body. The figure shows that this distribution was attained in about three hours. One-half of the deuterium taken in the experiment was excreted in 10 days. Since this was excreted at the same rate as ordinary water in the body the conclusion can be drawn that one-half of the water contained in the human body (i. e., one-third of its weight) is replaced every 10 or 12 days. MacDougall and coworkers (62) found, in a similar experiment with rats, that one hour was sufficient to allow thorough mixing of the body water of the rat with water taken into the stomach.

By using foods or drugs in which ordinary hydrogen is replaced by deuterium so as to introduce the tracer it is obvious that deuterium may sometimes be used to obtain information on the nature and the rapidity of normal physiological processes.

CONCLUSION

References to many excellent pieces of research on or with deuterium have been necessarily omitted. The examples cited are sufficient to show the possibilities opened up by the use of deuterium as a tool of research and the wide range of research fields to which it is applicable. Research with deuterium requires, in the majority of cases, careful physical measurements of some type and ingenious utilization of the small differences which exist between isotopic species. Wider use of deuterium as a tracer, in various fields of research, appears to offer the greatest promise for more extended contributions to future research.

Deuterium is probably only a fore-runner of the use of other isotopes as research tools. The separation of oxygen isotopes has been partially accomplished and Polanyi and Szabo (63) have used the heavier isotope of oxygen as a tracer to determine the mechanism of ester hydrolysis. The complete or partial separation of other isotopes will probably soon be an accomplished fact. Developments of this character will not affect the simpler aspects of our chemistry. They will, however, equip us with yet more tools to attack the myriad problems of science.

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ARTIFICIAL RADIOACTIVITY

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INTRODUCTION

I am speaking tonight on a very new subject, for artificial radioactivity was unknown fourteen months ago. Indeed, some of the facts I shall speak about were brought to light within this very month. From the standpoint of physics, the developments within the year have gone forward with almost incredible rapidity, with results that have profoundly modified and enlarged our understanding of the atom.

HISTORICAL BACKGROUND

For a historical background, however, we must go back to 1896, the year of Roentgen's discovery of x-rays. At that time Professor Henri Becquerel investigated the possibility that this mysterious radiation might be given off spontaneously from natural substances. He had in mind particularly the class of substances that give off light of their own accord—phosphorescent substances. Becquerel had been studying the properties of phosphorescent substances and happened to have in his possession at that time some phosphorescent salts of uranium, which he had prepared fifteen years before. Almost immediately he discovered that uranium salts do give off a radiation like x-rays; for when the uranium salts were placed near a photographic plate enclosed in a light-tight box, after a period of time the photographic plate was activated.

Very soon Rutherford, then at McGill, showed that the radiations continuously emanating from uranium could be divided into two types: one called the alpha rays, which were very easily absorbed in matter and produced intense ionization, and a much more penetrating type called the beta rays. When a still more penetrating type of radiation was discovered, Villard named them the gamma rays. These names for the three types are still used, although now it is known that the alpha rays are the nuclei or centers of helium atoms, the beta rays are high-speed electrons, and the gamma rays are indeed very penetrating x-rays, which are of the same nature as light.

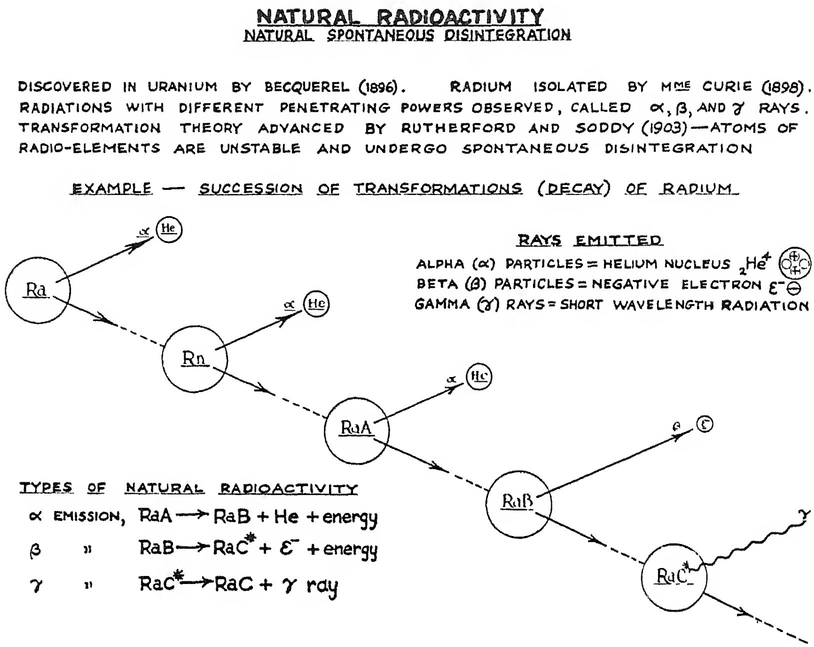
Soon other radioactive substances were discovered, and in 1898 Madame Curie isolated radium. At this stage a number of radioactive substances had been found. Some appeared to give off radiation continuously and constantly, while the radiation from others decreased with time.

This complicated mass of facts was reduced to order by the transformation theory of Rutherford and Soddy in 1903. According to this theory, the atoms of the radio-elements, unlike the atoms of the ordinary elements, are not stable, but undergo spontaneous disintegration, accompanied by the expulsion of an alpha or a beta particle. After the disintegration, the resulting atom has physical and chemical properties entirely different from the parent atom. It may in turn be unstable and pass through a succession of transformations, each of which is characterized by the emission of an alpha or beta particle.

These processes may be illustrated by considering the changes in radium, shown schematically in the first slide (Fig. 1). At any moment an atom of atomic mass 226 may become unstable and break up with explosive violence, expelling an alpha particle with a characteristic speed. Since the alpha particle is a helium atom of mass 4, the resulting atom is lighter than before and becomes an atom of a new substance, radon, of mass 222, which is an inert radioactive gas. This in turn breaks up, with the liberation of an alpha particle, and is converted into an atom of a nongaseous element, radium A. The next element in the series, radium B, emits a beta particle and thereby transforms into radium C, which is an element of very nearly the same weight and one unit up the periodic table.

For the purposes of the evening, this is all I need to say about the natural radioactive substances, the unstable atomic species existing at the present time in nature.

We now turn our attention to 1919, when Lord Rutherford for the first time transformed the ordinarily stable element nitrogen into oxygen. By this time Rutherford's theory of the atomic nucleus was well established. It was generally accepted that the nucleus, or center, of the atom contains more than 99.9 per cent of the atom's mass and energy and, moreover, that the nucleus possesses a positive charge that determines the number and configuration of the electrons outside the nucleus, and these extra-nuclear electrons determine the atom's



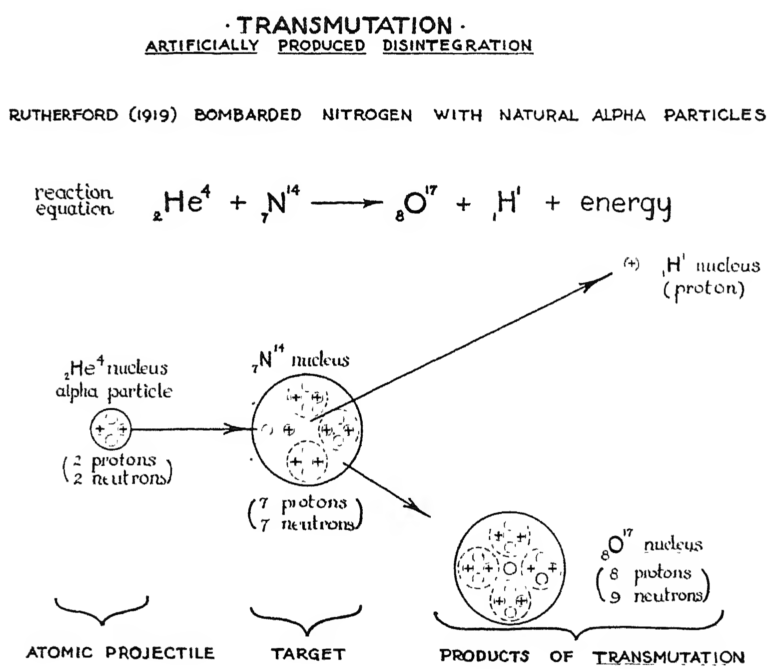
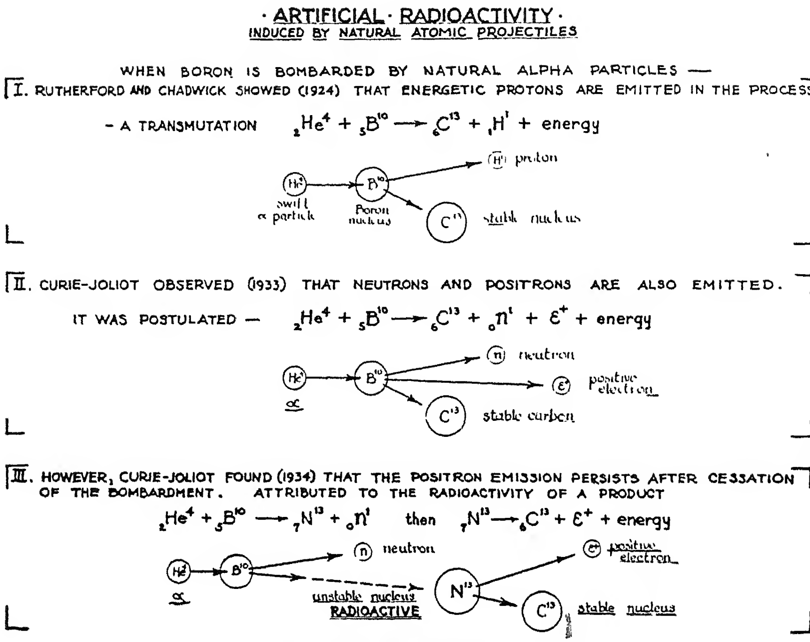


FIGURE 1—Upper. FIGURE 2—Lower.

place in the periodic table. Thus, on this theory, the age-old problem of alchemy, the conversion of one chemical element into another, was reduced to the definite problem of changing the amount of positive electricity in the atomic nucleus.

This Rutherford succeeded in doing by bombarding nitrogen with the alpha particles from radium. Several lines of evidence indicated that the constituent particles of the nucleus (then thought to be protons and electrons) were closely and tightly bound together, and that, therefore, disrupting the nucleus could be accomplished only by bombardment with atomic projectiles of very high energy, such as the alpha particles from radium. I should like to spend some time describing Rutherford's great experiments, for his works are classics in experimental physics, but time permits me only to state the established experimental results. He showed that when an alpha particle or helium nucleus, traveling at high speed, hits the nucleus of a nitrogen atom, occasionally the alpha particle sticks, and at the same time a proton, or hydrogen nucleus, is thrown off with a great deal of kinetic energy. Thus is formed O^{17}, a heavy form of oxygen which was not known in nature at that time but since has been discovered as a normal constituent of chemical oxygen by Giauque and Johnston—and by the way, the latter gentleman is Professor Johnston of your department of chemistry.

This classic nuclear reaction is shown in the next slide (Fig. 2). For most purposes, an atomic nucleus is sufficiently specified by giving the atomic number, which is the positive charge on the nucleus in integral multiples of the proton charge, that determines its place in the table of elements—what element it is—and the mass number, in multiples of the proton as well. Actually, in fact, atomic nuclei do not have masses that are exact multiples of that of the proton, but that need not worry us here. Thus the upper right-hand corner of the symbol of the element is reserved for the isotopic mass, and the lower left-hand corner for the atomic number, and the nuclear reaction of Rutherford is written as shown in the slide. The double charge on the helium nucleus is added to the seven-fold charge of the nitrogen, and the single charge of the hydrogen is subtracted, resulting in a net increase of one positive charge, thereby forming oxygen. Likewise, the net increase in weight is 3 units, making O^{17}.



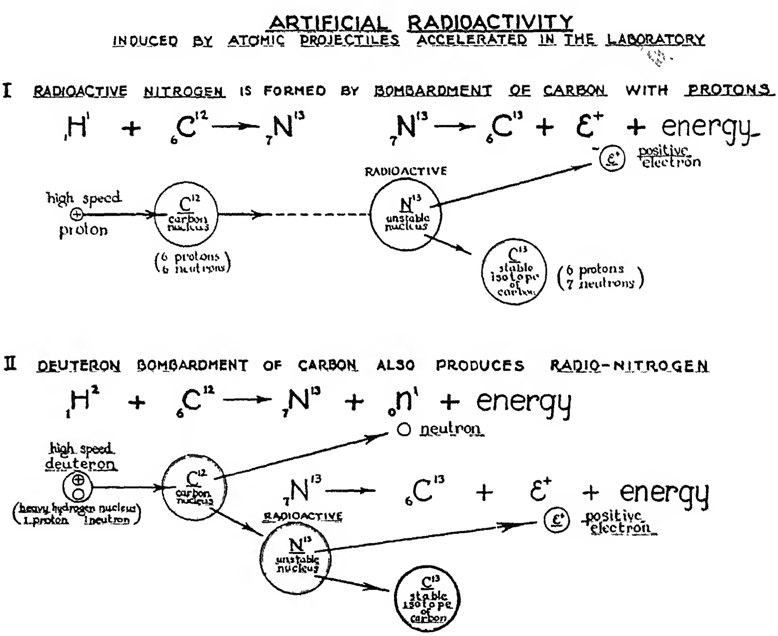


Figure 3—Upper. Figure 4—Lower.

Following the first definite example of the artificial transmutation of the elements, many other transmutations were carried out. Most of the lighter elements up to potassium were transformed, one into another, by alpha particle bombardment, in each case with the emission of a proton.

The next episode in our historical background brings us up to 1932, when Irene Curie, the daughter of Madame Curie, and her husband, F. Joliot, discovered that boron gives off positrons, the positive electrons discovered that same year by Professor Carl Anderson of the California Institute of Technology, and neutrons, the neutral particles of protonic mass discovered by Chadwick only a few months earlier. They concluded that the reactions depicted on the next slide (Fig. 3) occurred. When boron is disintegrated by alpha particle bombardment, alternative reactions may occur: either a proton may be emitted, as observed by Rutherford and Chadwick, or a neutron and positive electron together—as though a proton is not itself a simple particle but is made of a neutron and positive electron, and that sometimes the process of expulsion of the proton in the reaction is so violent that the proton itself is broken up into its constituent parts.

THE DISCOVERY OF ARTIFICIAL RADIOACTIVITY

The next episode is the birth of artificial radioactivity. One day, more than six months after they had first noticed the emission of positrons from boron bombarded by alpha particles, Curie and Joliot observed (accidentally, I believe) that the positron emission continued on after the alpha particle bombardment had been stopped—they happened to remove the radium from the vicinity of the boron. With this observation, they had discovered that a new kind of radioactivity is stimulated in boron by alpha particle bombardment. This discovery made it evident that the neutron and positron do not come off simultaneously when boron is bombarded by the alpha particle, but that the neutron in the reaction is emitted first, leaving a nucleus having a charge of 7 (hence, the nitrogen nucleus) and a weight of 13, which is lighter than ordinary nitrogen and presumably, therefore, unstable. They proved chemically that the radioactive substance formed is, in fact, an isotope of nitrogen, and christened it "radio-nitrogen." As shown in the slide, the positron emission converts the radionitrogen into C^{13}.

In those pioneer experiments they produced two other new radioactive substances—radio-magnesium and radio-silicon—and since that time other radio-substances from alpha particle bombardment have been discovered by various investigators.

In their first discussion of their important discovery, Curie and Joliot suggested that such radioactive substances might well be produced by bombardment with other atomic projectiles, especially protons, deuterons, and neutrons. This suggestion seemed to be almost a certainty to us in Berkeley. Since, for more than a year, we had been studying the disintegration of various elements under deuteron bombardment, and had observed the almost universal emission of protons and neutrons from bombarded targets, it appeared most plausible that the neutrons we had been observing so universally were involved in the alternative nuclear reaction in which artificial radioactive substances were formed.

In particular, it seemed likely that radio-nitrogen could be formed by a deuteron entering a C^{12} nucleus, forming N^{13}, with the emission of a neutron, or by the direct addition of a proton to the C^{12} nucleus, as shown in the next slide (Fig. 4). My colleagues, Dr. M. C. Henderson and Dr. M. S. Livingston, and I investigated this interesting possibility, and immediately we found that radio-nitrogen is formed, indeed, in both of these ways. In those first experiments we also bombarded various other substances with high-speed deuterons, and found, to our surprise and joy, evidence of the production of many new radioactive substances in addition to radio-nitrogen. At about the same time several other laboratories in the world, notably Cambridge, Washington, and Pasadena, more or less independently carried on investigations establishing that radioactive substances can be produced in this way.

In the intervening months, intensive work in the various laboratories has gone forward, with the result that a great many new radioactive substances have been produced, identified, and studied more or less extensively. Also, following the discovery of Professor Fermi, many new radioactive substances produced by neutron bombardments have been studied. Although the discovery of artificial radioactivity is hardly more than a year old, the facts that have been brought to light are already so extensive that I could hardly hope to give an adequate summary this evening. It therefore would seem desirable that I confine my attention for the remainder of the

time to some of the results of recent investigations carried on by my colleagues and myself in California.

EXPERIMENTAL METHODS

But before discussing experimental results, it is desirable to say something about experimental methods for accelerating protons and deuterons to high speeds. There is a natural tendency to relegate to the background the experimental methods and techniques and to regard the results brought to light in nuclear investigations as of first importance. It is so easy to forget that the nuclear investigations are made possible by the development of experimental methods and techniques. How greatly was nuclear physics enriched by the cloud chamber of C. T. R. Wilson!

Methods for the acceleration of charged particles can conveniently be classified into three types: First, the high-voltage method, in which the ions fall through a requisite difference of potential in a vacuum tube. The second method might be called the surf-board method, because the ions are caused to travel along in the field of a traveling wave. The third class of methods of accelerating ions might be termed "resonance methods," or methods of multiple acceleration.

The high-voltage method is, in a sense, the most straightforward, and has much to commend it and is widely used. In the classic experiments of Cockcroft and Walton, in which, for the first time, transmutations were accomplished by bombardment with accelerated ions, a vacuum tube capable of withstanding about 800,000 volts was used. Lauritsen and his collaborators in Pasadena have accomplished a great deal with a vacuum tube, across which is applied about a million volts supplied by the high-voltage transformers in the high-tension laboratory of the California Institute of Technology. Using a Van de Graaff generator, Tuve, Hafstad, and Dahl, in Washington, have been able to accelerate ions at voltages as high as 1.2 million. This high voltage was distributed along a long vaccum tube very nicely, by means of a series of electrodes maintained at proper differences of potential by the corona along the tube. Van de Graaff and his collaborators at Round Hill, Massachusetts, are constructing a similar type of tube in which the voltage is distributed between the electrodes by a series of resistances. The tube is ultimately intended to withstand the full voltage available from their gigantic electrostatic generator, which is more than five million.

Professor J. W. Beams, at the University of Virginia, during the past year or two has been engaged in the development of the surf-board method, and already has made such progress that it appears that the method will be very useful for producing small currents at very high voltage. Beams has already succeeded in accelerating protons to voltages above two million, and it appears not improbable that he will be able to reach double this voltage in this way. The inherent features of the method are such as to restrict it to the production of small current in pulses, a restriction which, however, makes it almost ideally adapted to cloud chamber experiments.

The methods of multiple acceleration by resonance with an oscillating electric field have the advantage that they do not require high voltages. The general resonance principle is familiar even to the layman. A child in a swing knows that a high swinging velocity can be achieved by one big push, corresponding to the single acceleration of an ion by application of high voltage, or by a succession of small pushes properly timed with the swinging motion, corresponding to the resonance acceleration of ions. One type of apparatus that uses this resonance principle involves both a magnetic field and an oscillating electric field. We have in our laboratory two of this sort. The larger one of the two, which has been used in the nuclear investigations that I shall speak about, is shown on the next slide (Fig. 5). The most prominent feature of the apparatus is the giant electro-magnet, weighing something like 85 tons. Thus far we have accelerated deuterons to energies only slightly above five million, and the most energetic deuterons we have actually used in nuclear investigations had energies of about 4.5 million volts. The time, of course, will come when we will want to go up to higher voltages, and from our recent experience we are confident that, by using the full power of the magnet, we will be able to produce deuterons of energies above ten million volts, and possibly above fifteen million volts.

The ions are accelerated in the vacuum chamber between the poles of the magnet. The function of the magnetic field is to cause the ions to travel with constant angular velocity most of the time in circular paths. Within the chamber there are two semicircular hollow electrodes, between which is applied a high frequency potential difference. The ions circulate

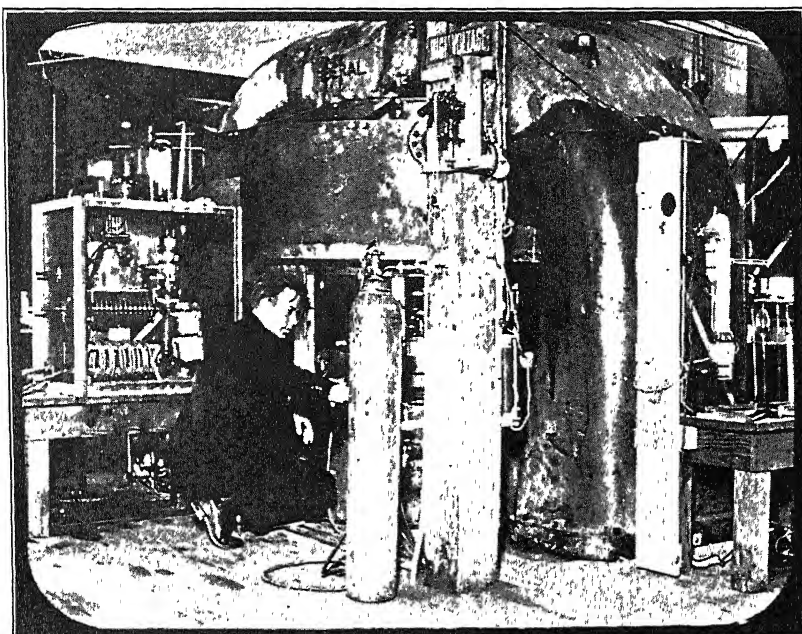


FIGURE 5

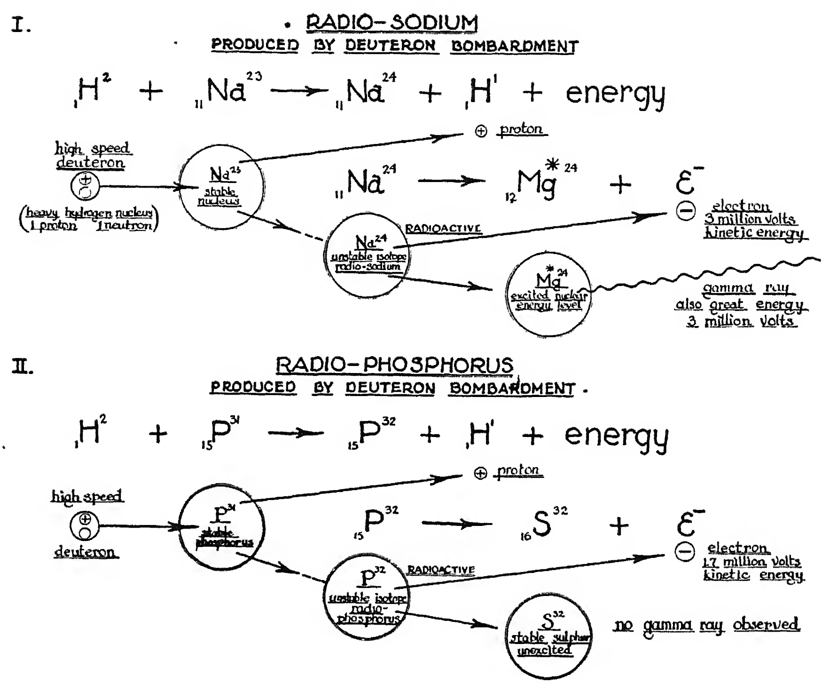

I.
RADIO-SODIUM
PRODUCED BY DEUTERON BOMBARDMENT
$_1H^2 + _{11}Na^{23} \longrightarrow _{11}Na^{24} + _1H^1 + \text{energy}$
proton
high speed deuteron
(heavy hydrogen nucleus 1 proton 1 neutron)
Na^{23} stable nucleus
$_{11}Na^{24} \longrightarrow _{12}Mg^{*24} + \varepsilon^-$
electron 3 million volts kinetic energy
RADIOACTIVE
Na^{24} unstable isotope radio-sodium
Mg^{*24} excited nuclear energy level
gamma ray also great energy 3 million volts
II.
RADIO-PHOSPHORUS
PRODUCED BY DEUTERON BOMBARDMENT
$_1H^2 + _{15}P^{31} \longrightarrow _{15}P^{32} + _1H^1 + \text{energy}$
proton
high speed deuteron
P^{31} stable phosphorus
$_{15}P^{32} \longrightarrow _{16}S^{32} + \varepsilon^-$
electron 1.7 million volts kinetic energy
RADIOACTIVE
P^{32} unstable isotope radio-phosphorus
S^{32} stable sulphur unexcited
no gamma ray observed

FIGURE 6

around from within one electrode to within another. and as they cross the diametrical region they gain increments of kinetic energy corresponding to the potential difference. Inasmuch as the angular velocity of the ions is determined by the magnetic field alone, they can be made to spiral around in synchronism with the oscillating electric field, with the result that they can be made to gain successive increments of velocity, and hence, going faster and faster on ever widening spirals, finally they emerge at the periphery of the apparatus where they are withdrawn by a deflecting electrostatic field through a thin aluminum window to the outside world. The swiftly moving deuterons travel a distance of about 17 cm before being stopped by their loss of energy in passing through air. The beam is visible as a bright blue glow; for the beam passing through the air excites the atoms and molecules to the emission of visible light. Experiments on the radioactivity induced by deuteron bombardment are carried out simply by placing the substance to be bombarded in the path of the deuteron beam just outside the aluminum window for any desired period of time, and then, taking the bombarded target away to an ionization chamber or a Wilson cloud expansion chamber, or any other apparatus used for studying the radiation given off from the activated target.

THE NEUTRON-CAPTURE REACTION

I have already remarked that in our first experiment, in which we bombarded various substances with deuterons, there was evidence of the formation of several new radioactive substances. In some cases, radioactive nuclei are formed in nuclear reactions, in which neutrons or alpha particles are emitted. But in the majority of cases it is found that the neutron of the deuteron is captured and the proton is emitted with high speed. This general type of reaction, which, for convenience, is called the neutron-capture reaction, has been observed to occur for many of the elements, and is conveniently illustrated by the cases of radio-sodium and radio-phosphorus shown in the next slide (Fig. 6).

Thus Na^{23}, upon being bombarded by the deuterons, acquires the neutron of the deuteron and becomes heavier by the weight of the neutron, that is Na^{24}. Na^{24} does not occur in nature and is energetically unstable, and in the course of 15½ hours, on the average, the radio-sodium atom emits a high-speed electron

(i. e., a beta particle) from its nucleus, becoming Mg^{24}. The newly created magnesium nucleus is formed with an excess of energy, which it immediately radiates as a very energetic gamma ray of energy above three million volts. The beta and gamma rays emitted from radio-sodium are thus more powerful than the radiations from radium. Indeed the gamma rays are more powerful than those from any of the known natural radioactive substances.

In a like manner, radio-phosphorus is formed. Radio-phosphorus is interesting in two respects. In the first place, it has the longest average lifetime of any of the artificial radio-active substances thus far studied. Its half-life is about 15 days. The other interesting feature of radio-phosphorus is that it does not emit any gamma rays. A pure beta ray spectrum is observed. It appears that the S^{32} nucleus, that results when P^{32} emits a beta particle, is formed in its normal state without an excess of energy to be radiated.

THE TRANSMUTATION FUNCTION FOR THE NEUTRON-CAPTURE REACTION

Perhaps the most interesting result of all was the mere fact that we were able to transform elements of as high atomic number as sodium and phosphorus by bombardment with deuterons of less than two million volts of energy. It was quite incomprehensible that deuterons of such low energy were able to overcome the high repulsive forces of the positive charges on these nuclei, for it was presumably well known that these repulsive forces produce an effective barrier around the nuclei corresponding to several million volts.

Prior to the advent of the wave mechanics, it was thought that a charged particle bombarding a nuclear potential barrier does not penetrate into the nucleus unless it has enough energy to climb the nuclear wall and enter over the top, and so, in accordance with classical ideas, one would not expect sodium to be transformed by bombardment with two million volt deuterons. But Gurney and Condon, and Gamow, independently applied the wave mechanics to nuclear problems and made it clear that charged particles penetrate right through nuclear potential barriers. Indeed it was the existence of this tunnel effect that encouraged Cockcroft and Walton to try to disintegrate lithium by bombardment with protons of less than a million volts energy, with the result that is now so well known.

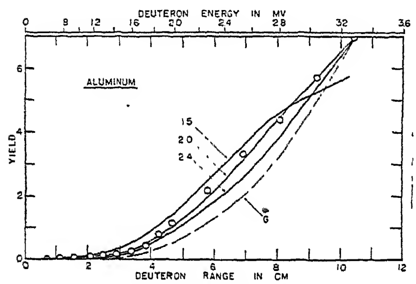
But even the Gamow theory did not make plausible the observation of the transformation of sodium by one and one-half million volt deuterons. The apparent incompatibility of the experiments with current theory was enhanced by the further observation that copper could be rendered radioactive by bombardment with deuterons of slightly more than two million volt energies.[1] Thus it was of much interest to my colleagues, Drs. R. L. Thornton and E. M. McMillan, and myself, to investigate the variation of the nuclear reaction with the energy of the bombarding deuterons in the several cases, which we did as follows:

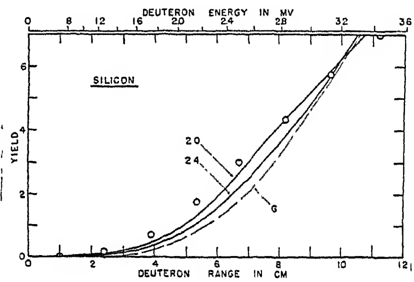
In order to obtain an energy-yield curve for a reaction giving a radioactive product, one measures the intensity of activation of a number of samples exposed to bombardment by particles of different energies. The relative bombarding current and exposure time must be accurately known for each sample, a requirement which is most easily and satisfactorily met by activating them simultaneously. This was done by using as a target a stack of thin foils of the substance being investigated, through which the activating deuteron beam was sent. The energy of the deuterons traversing any particular foil is then determined by their initial energy, and the stopping power of the preceding foil and the measured activities give directly the differential excitation curve. Thus, for example, a stack of 15 aluminum foils, each having a stopping power of about 8 mm. air equivalent, was placed in the beam of the deuterons emerging from the aluminum window of the magnetic resonance accelerator, and, after exposure to the beam for a few minutes, was removed, and the radioactivity induced in each foil was observed by placing the individual foils in the ionization chamber of an electroscope.

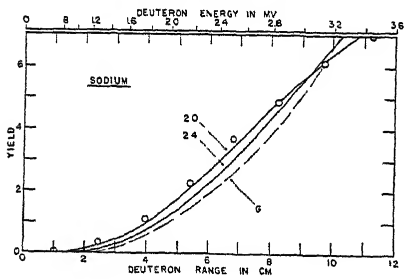
The variation of the probability of activation of an aluminum nucleus with the energy of a bombarding deuteron (sometimes called the differential excitation function, or thin target transmutation function) thus observed, is shown in the next slide (Fig. 7). I am showing the aluminum results first because it it believed in this case the observations were most

[1]Recently we have made preliminary observations that indicate that radio-molybdenum is formed by bombardment of molybdenum with 3.5 million volt deuterons, and that possible gold is rendered radioactive by bombardment with 4.5 million volt deuterons. However, further work must be carried out before it can be concluded with confidence that these deuteron reactions actually occur, as there are yet possibilities of contaminations.

precise. For similar observations on radio-sodium and radio-silicon, thin mica foil was used, as mica contains both silicon and sodium. Since the half-life of radio-silicon is 2.8 hours, and that of radio-sodium is about 15.5 hours, the two radioactivities were readily distinguished in the mica foil, the silicon activity being predominant in the first few hours after deuteron bombardment, and the sodium activity persisting for days afterwards. The results in these two cases are shown in the next two slides (Figs. 8 and 9). The observations with copper foils are shown in the last slide (Fig. 10).







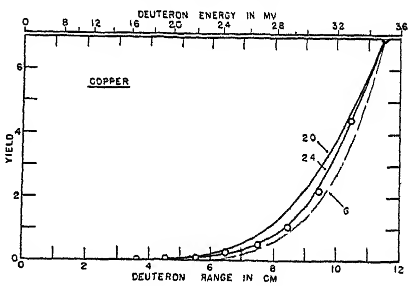


FIGURE 7—Upper left.
FIGURE 9—Lower left.

FIGURE 8—Upper right.
FIGURE 10—Lower right.

It is evident that the excitation curves in the four cases are of similar form. The yield of radioactive substance for a thin target, plotted against the range of the bombarding deuteron, instead of its energy, rises approximately linearly with the range (with a "tail" at the beginning). The experimental results clearly indicated a new general kind of excitation function for this class of nuclear reactions.

THE OPPEMHEIMER-PHILLIPS THEORY

We were all curious to know something about the fundamental physics underlying this new type of transmutation

function, and Professor J. R. Oppenheimer and Dr. Melba Phillips soon came forward with a theory that explained everything in most gratifying fashion. The essence of their theoretical explanation lies in the fact that reactions of the type here concerned can occur without requiring the penetration of a charged particle through the nuclear coulomb potential barrier which opposes the entry of the deuteron. The mechanism postulated can be described in the following way: Consider the deuteron as built of a proton and neutron with the binding energy I. Because of the wave nature of the particles, this structure is not confined within a sharply limited volume, but there is a finite chance that the neutron or proton may be found some distance away from the center of mass. This chance decreases rapidly with the distance. When the deuteron is projected against the nucleus, the proton is held back by the coulomb field. This distorts the probability distribution of the proton in such a way that, for a given distance of the deuteron center of mass from the nucleus, the chance of finding it in the center of the nucleus is very much reduced. On the other hand, the neutron is immune to the action of the electrostatic field, and its probability distribution can overlap the center of the nucleus; this distribution is, in fact, distorted by the forces involved in the deceleration of the neutron in such a way as to increase its density on the side toward the nucleus. Therefore the neutron has a relatively larger chance of being within the nucleus, and while there, of undergoing a reaction in which it becomes bound, forming a new nucleus. The extension of the neutron distribution varies with I, becoming greater as I decreases. It is the relatively small value of I (about 2 million volts) that causes the slow energy variation of this type of reaction by flattening out the neutron probability distribution.

The actual shape of the curves giving the variation of the neutron-penetration with energy depends on the value of I. Since this most probably lies between 2 and 2.4 million volts, as indicated by other experimental evidence, the curves for these two cases have been compared with the experimental values. They are plotted as solid lines, as shown in the several slides. The ordinates of the theoretical curves are adjusted to make them fit at the highest experimental point, except in the cases of sodium and silicon, where the measured values of these are almost certainly too low because of recoil effects.

The Gamow function is also plotted on the figures as dotted lines for comparison. It is seen that the results are in gross disagreement with the Gamow theory, but on the other hand, the results of Oppenheimer and Phillips show a very satisfactory agreement with the observed values. Consider the first case of aluminum, which is the most trustworthy experimentally. With pure aluminum foils the activity if very large compared to that of any possible contamination. There is no error in the highest point caused by recoil. It is seen that the Oppenheimer-Phillips function with I = 2.0 fits extremely well, while with I = 1.5 and I = 2.4 it is off by more than the experimental error.

The fit for sodium and silicon is also best for I = 2.0. Here the possibility of experimental error is somewhat greater, and the apparent deviation in the case of silicon between 1.5 and 2.5 million volts may not be real. The results for these two elements are of chief interest in showing that this type of excitation curve is not a characteristic of any particular reaction, but of a class of reactions. The comparative values for sodium and silicon show also that the steepness of the curve increases with atomic number, as it should.

For copper the fit seems to be best with I = 2.4. Here, because the greatest variation of the function occurs in a narrower voltage range, the different theoretical curves are not as widely separated as in the other cases, and the apparent better agreement with I = 2.4 may not be real.

Thus the theory of Oppenheimer and Phillips, which was developed from such attractively simple and reasonable assumptions, is adequate to explain the observed excitation curves. The agreement of the experiment with the theory is so satisfactory in detail that the results yield a completely independent measure of the binding energy of the deuteron, and this result itself is of much importance.

Moreover, acceptance of the Oppenheimer-Phillips theory as correct leads to another very important conclusion. Just as the variation of the transmutation yield with energy for a given atomic number is slower than expected on the Gamow theory, likewise the variation with atomic number for a given energy is much slower. This has the consequence that it will be possible, with the available deuteron energies, to produce nuclear reactions much farther up the periodic table than one could have hoped for before.

UTILITY OF ARTIFICIAL RADIOACTIVITY

Before closing it is well to remark that, now that radioactive forms of many of the elements can be manufactured in the laboratory, many new avenues of research are opened up. It is reasonable to expect that artificial radioactive substances will play a possibly more important role in the physical and biological sciences in the not distant future than the natural radioactive substances have in the past. Certainly extensive study of the artificial radioactive substances will lead to a greatly enlarged understanding of atomic structure. But, more particularly, these new radioactive substances provide many and varied ideal sources of beta and gamma rays. For example, radio-phosphorus provides beta radiation, free from gamma rays, that can be used conveniently for studies of the behavior of high-speed electrons in matter. Also some of the new radioactive substances give off gamma rays that are far more energetic and penetrating than any from the natural radioactive substances, and the use of these gamma ray sources undoubtedly will lead to important advances in our knowledge of the interaction of radiation and matter.

There may result also many important biological applications. I hesitate to express views in this direction, but some of my medical colleagues think it quite possible that the discovery of artificial radioactivity will ultimately be of great importance to medicine. Opinions of this sort, of course, are highly speculative, and I leave it to you to estimate the advantages for radiation therapy and biological research, of radioactive substances having practically any desired chemical and physical properties.

In conclusion, may I say that, while I have not given you a comprehensive survey of this new world of knowledge and investigation, I do hope that I have given enough of an account of things that have interested us in California in recent months, to make it clear that there is a new science—shall we call it nuclear physics or shall we call it nuclear chemistry?

NUCLEAR TRANSFORMATIONS AND THE ORIGIN OF THE CHEMICAL ELEMENTS

G. GAMOW
George Washington University, Washington, D. C.

Until the beginning of this century the chemical elements have been considered as certain prime substances, and corresponding atoms as elementary constituent parts from which more complex molecules can be built up. The discovery of radioactive phenomena and their interpretation, due to Rutherford, as the spontaneous disintegration of atomic nuclei has shown, however, that chemical elements can be, under certain circumstances, transformed into one another and such transformations occur spontaneously for the heaviest of the known elements. Rutherford succeeded also, as early as 1919, in producing artificial transformations of light, usually stable, atoms, bombarding them with the intensive beams of fast α-particles. The first element which was disintegrated in such a way was nitrogen, which in the collision with an α-particle emits a proton and is transformed into a heavier isotope of oxygen. The corresponding nuclear reaction can be written in the form:

$$_7N^{14} + {}_2He^4 \rightarrow {}_8O^{17} + {}_1H^1. \tag{1}$$

Further investigations of Rutherford and his school have shown that analogous processes can happen for the most of the light elements and that the probability of disintegration decreases very rapidly with increasing atomic number so that already for $Z > 20$ no emission of protons can be observed. It was also found that the probability of disintegration increases very rapidly with increasing energy of the bombarding α-particles. Both observations can be satisfactorily explained by the theory of artificial nuclear disintegrations worked out by Gamow according to which the probability of such transformations depends on the transparency of the potential barrier surrounding each nucleus and preventing the incident α-particles from entering the nuclear structure. The theoretical expression for the transparency of such barriers for incident α-particles can be worked out on the basis of modern wave-mechanics

and is in very good agreement with the detailed results of experiments (*1*).

Gamow concluded from this theory that the transparency of nuclear barriers must be much larger if the bombarding particles are protons. Due to the smaller charge and mass of a proton, the probability of penetration of a proton into a given nucleus is the same as for an α-particle with 16 times larger energy. Remembering that nuclear transformations have been observed by Rutherford only for α-particles with the energies of several million electron-volts, one could conclude that in the case of proton-bombardment one can expect observable results already for energies of a few hundred kilovolts. These considerations encouraged Cockcroft to construct special high-voltage apparatus in which he could produce the beams of protons with the energies up to 500 kilovolts for the use of nuclear bombardment. Bombarding with these protons a target of lithium he was able to observe the expected nuclear transformation at voltages as low as 250 kilovolts (*2*). In this case the proton penetrates into the nucleus of the lithium atom and breaks it up into two α-particles. The reaction can be written in the form:

$$ {}_3Li^7 + {}_1H^1 \rightarrow {}_2He^4 + {}_2He^4, \tag{2} $$

with the liberation of a large amount (about 18 x 10^6 e. v.) of energy. Bombarding by his proton-beams different light elements, Cockcroft was able to find other examples of the reactions of the same type and to prove the validity of the theoretical formula for the probability of artificial disintegration. At the present time various ingenious apparatuses producing fast beams of particles have been developed in different laboratories throughout the world, increasing our knowledge concerning different types of artificial transformations of light elements. It has been mentioned above that due to the decreasing transparency of nuclear potential barriers the reactions of such type can be observed by present voltages only in the region of light elements and one requires proton-beams of about 10 x 10^6 e. v. in order to penetrate into the nuclei of such heavy elements as mercury and lead.

Quite a new type of nuclear reactions was recently discovered by Fermi (*3*), who was able to show that the nuclei of different, especially heavy, elements bombarded by neutrons can be transformed into their heavier isotopes. Such "capture" phenomena can only be explained as the sticking of incident

neutrons to the bombarded nucleus with the liberation of surplus energy in the form of γ-radiation. It was observed by Fermi that the probability of such radiative capture of neutrons increases with their decreasing energy and that one can observe the maximum effect for those neutrons slowed down by collisions with other nuclei to their ordinary thermal velocities. One can easily understand that such type of nuclear reaction can happen without difficulty also for heavy nuclei since, due to the absence of repulsive forces between the neutron and the nucleus, there is no potential barrier preventing the penetration of the neutron into the nuclear structure. The theory of radiative capture of slow neutrons by heavy nuclei was worked out by Bethe and is in satisfactory agreement with the experimental evidence. The heavier isotope formed as the result of the capture of a neutron by certain nuclei can be unstable and subject to the spontaneous emission of an electron which leads to the formation of a nucleus with larger charge and larger mass than the original one. Thus the radiative capture of neutrons and consequential β-disintegration leads step by step to the formation of more complex nuclei. As the typical Fermi-reaction one can write down the process of radiative capture of a neutron by the nucleus of ${}_{53}I^{127}$:

$$\left.\begin{aligned} {}_{53}I^{127} + {}_{0}n^{1} &\rightarrow {}_{53}I^{128} + h\nu \\ {}_{53}I^{128} &\rightarrow {}_{54}Xe^{128} + \bar{\beta} \end{aligned}\right\} \tag{3}$$

leading to the nucleus of ${}_{54}Xe^{128}$.

Turning our attention from the experimental evidence obtained in the laboratories to the processes happening in the universe, we may at once conclude that there is not much chance for the nuclear reactions to occur around us on the earth. In fact the probability of nuclear transformation by the velocities corresponding to ordinary temperatures is extremely small and need not be taken into account. Only neutrons can produce nuclear transformations at small velocities, but all neutrons are already hidden inside of different stable nuclei and in order to get them out one must use very fast beams of protons or α-particles. If, however, we consider the processes happening inside of stars, in the hottest places of the universe, the situation might be rather different; in fact, the thermal velocities corresponding to several million degrees centigrade are already sufficient to produce artificial trans-

formations of the lightest elements. Using Gamow's formula for the probability of nuclear transformations by collision, Atkinson and Houtermans (*4*) calculated the chance for a proton, moving with thermal velocity, to penetrate into the nuclei of different elements and estimated the periods of time necessary for 50% transformation of different substances mixed up with hydrogen under the conditions governing inside of our sun (density $\sim$1; temperature $\sim$60 x 10^6 °C.). They obtained the following numbers: for *Li*, 34 min.; for *B*, 14 years; for *Ne*, 1 x 10^9 years; and for *Pb*, 10^{61} years (!), which shows that only the lightest elements are easily transformed by proton-bombardment under the conditions governing in the interior of stars. Making the same calculations for collisions with helium-nuclei (α-particles) one obtains very small probabilities even for the lightest elements so that such processes are very improbable even at intrastellar temperatures; still smaller probabilities are obtained for the disintegrative collisions with heavier particles. Thus the thermal nuclear transformations in stars are of importance only for the lightest elements and are entirely due to the collisions with hydrogen atoms which are always present in large amount in stellar substance.

The discovery of the radiative capture of neutrons by heavy nuclei opens, however, new possibilities for the intrastellar nuclear reactions. The neutrons which can be ejected from the nuclei of light elements by collisions with protons may stick to the nuclei of different heavy elements thus securing the possibility of the formation of still heavier nuclei. It might be that this effect plays a very important role in the formation of different elements in the interior of stars.

We come now to one of the most interesting questions concerning the physical state of the matter deep inside of stars. It is of course clear that due to extremely high temperatures and pressures in these regions all molecules are dissociated into separate atoms and even more all atoms are completely ionized, all electronic shells being torn away from the nuclei by the violent collisions. We may consider the substance inside of a star as the mixture of bare nuclei and free electrons, a mixture which can be treated as the ordinary mixture of two ideal gases: nuclear gas and electronic gas. Now, due to the fact that the average number of electrons in the atom is about fifty per nucleus, the partial pressure of electronic gas will, according to Dalton's law, form about 98% of the total pressure and is the only one which must be taken into account.

The equilibrium problem between the pressure of the electronic gas in the star's interior and the gravitational pressure of the outside layers of the star was considered by Landau (5) and we give here a short account of his calculations. The pressure of an ideal gas containing N particles in the cube with the side l is, as is well known, given by:

$$P = \frac{1}{6} \cdot \frac{N}{l^2} \cdot n \cdot p = \frac{1}{6} \cdot \frac{N}{l^2} \cdot \frac{v}{l} \cdot mv, \qquad (4)$$

where v is the velocity of particles, $n = \frac{v}{l}$ the number of collisions of a single particle with the wall per second and p the momentum equal to mv in the nonrelativistic case. For the ordinary isothermic compression $v = const.$ and the pressure P is inversely proportional to l^3; i. e., directly proportional to the density $\rho = \frac{N}{l^3}$. (Boyle-Mariotte law).

If, however, l becomes very small, the motion of different particles of our electronic gas must be quantised and no more than two electrons may stay on the same energy level (Pauli principle). With still decreasing l (increasing density), the distances between quantum levels become larger so that finally all levels will be densely occupied by electrons (this state is called saturated Fermi-gas), and the further compression must be inevitably connected with the increase of the velocity v. According to the fundamental relation of quantum theory, the momentum of the particle moving in the space of linear dimension l is given by:

$$p \sim \frac{h}{l},$$

where h is the quantum-constant; thus for saturated gas the momentum is inversely proportional to l. As far as the momentum is small compared with mc (velocity v small compared with the velocity of light), we can use the relation $v = \frac{p}{m}$, which means that the velocity itself is inversely proportional to l. The formula (4) shows us that in this region of densities the pressure P is inversely proportional to l^5; i. e., directly proportional to $\rho^{5/3}$. For still larger densities the average velocity

of the particles approaches the velocity of light. After this limit we must write $n = \frac{c}{l}$ for the number of collisions and still use the formula (5) which is correct also in the relativistic case (the increase of p is here due to the increase of the mass

$$\left(m = \frac{Mo}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} \right)$$

We see that for such large densities the pressure P varies as $\frac{1}{l^4}$ or as $\rho^{4/3}$. The diagrammatic representation of the (p, ρ)-relation for the ideal electronic gas is shown on Fig. 1, by the curve I.

The outside pressure P' due to gravitation is, as is well known, proportional to $\rho^{4/3}$ and the coefficient of proportionality depends on the total mass M of the star. The curves II′, II″ and II‴ represent (P', ρ)-curves for three different masses. We see that if M is small (curve II′) the inside pressure will be always larger and the star will expand and cool down until it will be turned into a large piece of stone. For somewhat larger mass (curve II″) there is a state of stable equilibrium between P and P' and the finite stage of the star will have inside a region filled up with nonrelativistic saturated Fermi-gas. For still larger masses (curve II‴) the inside pressure will never be able to oppose the weight of stellar substance and the star would collapse into a mathematical point (!) unless the further compression would be stopped by intranuclear repulsive forces between the particles of nuclear gas. This will happen when the distance between the particles is of the order 10^{-12} cm.; i. e., when the density approaches the value of 10^{12} relative to water! Thus we come to the conclusion that such a star will have in its center a very dense nucleus differing from the atomic nuclei only by its size which can be several miles in cross section. By calculations still further elaborated Landau was able to show that the limiting mass for which the stellar nucleus must be formed is about one third of the mass of our sun. Consulting astronomical data we find that this corresponds to the lower limit of stellar masses, which means that *all stars possess such nuclei which evidently represent the sources*

of the stellar energy radiated in such large amounts into interstellar space.

The question of the mechanism of energy-liberation is not yet quite clear but one can easily see that the gravitational energy alone liberated in the compression (Helmholtz's old theory) to such large densities would be enough to secure sufficiently long periods for stellar lives.

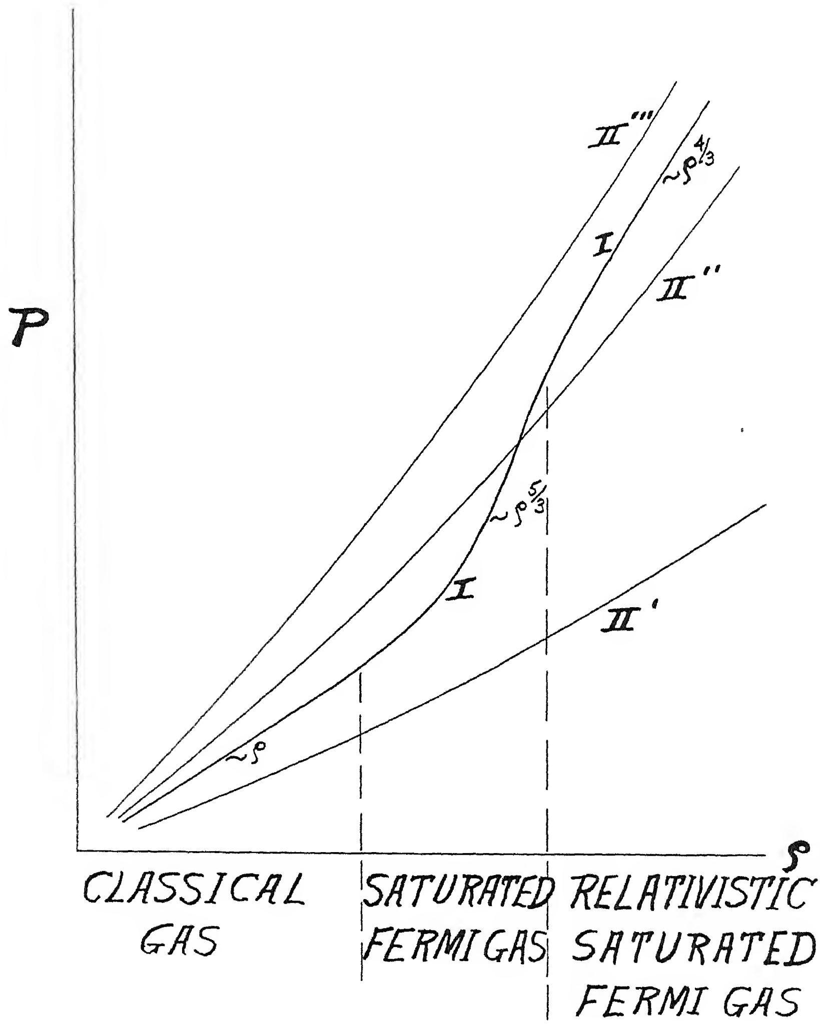


FIGURE 1

In this article we are interested especially in the role played by stellar nuclei in the formation of heavy elements. One can easily imagine that the stellar nucleus may not be considered as an inactive globe. The eruptive processes from its surface will throw out the small pieces of nuclear substance which coming into the outside layer of the star will immediately disintegrate giving rise to the nuclei of different stable and radioactive elements.

We see thus that there are many different phenomena inside of a star giving rise to formation and transformation of different elements and the hope may be justified that further investigation will clarify the relative importance of various processes and lead to a complete explanation of the relative abundance of different elements in the universe.

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The Genetic System

This book is a radical departure from the usual genetics text. It is a careful, scholarly, point-by-point analysis of the materials and methods of genetics. One by one the assumptions and principles of heredity are held up to the light of scientific inspection, scrutinized, and evaluated. The formal logic, the one-two-three arrangement of points, and the insistent and almost exclusive use of Drosophila material, become almost monotonous by the time the reading of the volume is completed. One finds himself with the feeling that simple things have at times been made more difficult than necessary.

The distinction between heredity and the mechanism of heredity has been relegated to the past, and the author considers the facts and principles of inheritance under the broad heading of The Genetic System. The book is scantily illustrated, and the use of symbols for genes is far from consistent throughout the book. The mathematical implications of various systems of mating in populations, the question of equilibrium in populations, and their important corollary, the gene-frequency method, are not mentioned. An excellent chapter on the relation of characteristics to the environment provides a welcome break in the didactic presentation. The final two chapters, on chromosomal aberrations and mutations, respectively, are likewise warmer in tone and less painfully formal than the earlier chapters.

In the opinion of the reviewer, the book is unsuitable for an elementary text in genetics, but provides an excellent critique and a good lesson in logic for the more advanced student of genetics who wishes to review and "fix" his knowledge of the subject.—L. H. S.

Genetics, by H. S. Jennings. xiv+373 pp. New York, W. W. Norton & Co. 1935.

Vertebrates Through the Microscope

This volume presents a compact, concisely-written account of vertebrate histology, unique in that it is not centered around man and medical histology. System by system the microscopic anatomy of various forms is taken up on a descriptive basis. Widely varying vertebrate forms are used as examples, and the student is encouraged to discern the variations between the general descriptions given in the text and the specific form he may be studying at the time. The book is fully and excellently illustrated with diagrams and photomicrographs, mostly original. An excellent chapter on the blood cells presents clearly the differential classification based on the new supra-vital technique. Another very worth-while chapter is concerned with the histology of the endocrine glands. The final chapter is a concise outline of general histological technique. References accompany each chapter, with a general text reference at the end of the book.—L. H. S.

The Microscopic Anatomy of Vertebrates, by George G. Scott and James I. Kendall. 306 pp. Philadelphia, Lea and Febiger. 1935.

Pacemakers

This, the first of a proposed new series of monographs on experimental biology, deals with certain mechanisms underlying vital processes. The master reactions, or pacemakers, controlling the dynamic steady state, are presented and analyzed, as keys to the understanding of protoplasmic events. These are of the utmost importance to students of the behavior of living organisms, whether these students call themselves biochemists, biophysicists, physiologists, botanists, zoologists, behaviorists, or psychologists. To bring out the central idea that a great deal of the overt behavior of organisms is determined by the interrelations of chemical events within cells and groups of cells quite independently of external environmental factors, the work of many investigators is presented and correlated. Chief among these are Osterhout and his colleagues, Parker, Crozier and their students, and the author and his own students. The various phenomena chosen as the basis for the correlated conclusions are permeability, growth, bioelectric effects, rhythmic activity, lateral line effects, sensory adaptation, and the physiology of the sense of time. The author is to be congratulated on bringing together in unified form such a series of interrelated phenomena. We wish success to this new series of monographs.—L. H. S.

Pacemakers in Relation to Aspects of Behavior, by Hudson Hoagland. x+138 pp. New York, the Macmillan Co. 1935.

How Good is Best?

The question of the range of human capacities and the comparative abilities of men becomes of importance in our present attempts at social reorganization. Are the seemingly great differences between men real or only apparent? The author of this unique volume concludes that the differences which separate the mass of mankind from one another are small, the ratios of the extremes of any given trait or ability, whenever measurable, falling within the limits of 1.3 and 2.5. The implications of this fact are discussed in detail. The point is made that genius represents only an added increment of qualities existent in all men, the increment at this point in the scale resulting in more profound changes than at others; much as an added degree of heat applied to water at 99° may profoundly change its characteristics, yet this added degree being no more of a quantitative increment than any other in the process of raising the water to a temperature of 99°. The raw data from which the conclusions of the book are drawn are given in full in appendices. It is quite certain that the responses of various readers of the volume will vary considerably in the degree of acceptance of the treatment and conclusions, yet it is imperative that the book be critically read by biologists, psychologists, sociologists, economists and statisticians.—L. H. S.

The Range of Human Capacities, by David Wechsler. ix+159 pp. Baltimore, the Williams and Wilkins Co. 1935.

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THE VISCOSITY AND FLUIDITY OF AQUEOUS POTASSIUM FERROCYANIDE SOLUTIONS[1]

G. RAYMOND HOOD AND JOHN C. WILLIAMS

The viscosity of aqueous electrolyte solutions is occupying considerable attention at the present time. The empirical equation put forward by Jones and Dole (1) relating the relative fluidity $\varphi = \varphi_c/\varphi_o$, to the square root of the concentration, c, (in mols per liter):

$$\varphi = 1 - A\sqrt{c} + B.c + \ldots \qquad (1)$$

has been theoretically derived from considerations of the Debye-Huckel theory (2) as:

$$\eta = \frac{\eta_c}{\eta_o} = 1 + A\sqrt{c} + \ldots \qquad (2)$$

and the Falkenhagen constant *A* for a dozen electrolytes has been evaluated experimentally through numerous recent measurements (3) and the interpretation of some earlier viscosity data (4).

Theoretically, the value of *A* must be positive for electrolytes, and zero for non-electrolytes. Experimental verification of the equation is given in Table I.

In the course of some investigations in progress in this laboratory, we found occasion to measure the viscosities of dilute aqueous solutions of potassium ferrocyanide with sufficient accuracy to warrant interpretation of our results in the light of the interionic attraction theory as a test of the Falkenhagen equation when applied to an electrolyte of the uni-tetravalent type.

[1]Contribution from the Chemical Laboratory of Miami University, Oxford, Ohio.

EXPERIMENTAL

Apparatus.—The viscometer was of the Bingham variable-pressure type, constructed of Pyrex glass. Details of the apparatus are elsewhere described (3d, 7); it may be noted here that the pressures used ranged between 110 and 125 cm. of water, the pressures being estimated to the nearest 0.01 cm.;

TABLE I

Comparison of Theoretical and Experimental Values of A in Eq. (1)

Solute	Temp.	A (Theory)	A (Found)	Reference
NH_4Cl	25°	0 0050	0 0057	3 f
LiCl*	25°	0 0237	0 0240	6
KCl	18°	0.0049	0 0052	3 a, b
KCl	25°	0 0050	0.0052	3 f, g
KCl	35°	0.0052	0 0051	3 b
KBr	25°	0.0049	0 0047	3 g
$KClO_3$	18°	0 0051	0 0028	3 d
$KClO_3$	18°	0 0051	0 0050	3 b
$KClO_3$	25°	0 0054	0 0050	3 f
$KClO_3$	35°	0 0058	0 0049	3 b
$KBrO_3$	25°	0.0058	0 0058	3 f
$LiIO_3$	18°	0 0094	0 0108	4 c
HNO_3	18°	0 0021	0.0021	3 b
HNO_3	35°	0 0025	0 0023	3 b
$LiNO_3$	18°	0 0069	0 0082	4 a
KNO_3	25°	0 0052	0 0050	3 f
$RbNO_3$	18°	0 0049	0 0070	3 c
$RbNO_3$	18°	0 0049	0 0050	3 b
$RbNO_3$	25°	0 0051	0.0040	3 c
$RbNO_3$	35°	0.0054	0.0056	3 b
$CsNO_3$	18°	0 0048	0 0103	4 b
$CsNO_3$	25°	0 0050	0 0043	3 f
$BaCl_2$	18°	0.0145	0 0140	3 e
$BaCl_2$	25°	0 0147	0 0201	1
Sucrose	25°	0	0	3 f
Urea	18°	0	0	5
Urea	25°	0	0	3 f, 5

*Note: In acetone.

the times of flow ranged between 1,325 and 1,925 seconds, the times being read to the nearest 0.1 second; while temperatures were read to 0.001° and the bath surrounding the instrument was controlled to ± 0.003° C. with a Beckmann thermometer. The probable error of a determination of relative viscosity as the average of a pair of observations (from 5 determinations of the viscosity of water at 18° involving 13 observations)

obtained with the instrument by one of us, was computed by the method of least squares as 0.008 percent. Much practice is needful in attaining this precision, just as it is in other skills which depend upon exact co-ordination of hand and eye; and the mean error of the measurements carried out by the junior author and herein recorded amounts to 0.03 percent.

Materials.—Solvent: Ordinarily distilled water was redistilled from alkaline permanganate, and then distilled very slowly for a third time.

Solute: The potassium ferrocyanide was "Coleman and Bell's" C. P. quality, used as received.

Solutions were not optically clear, i. e., they showed some Tyndall effect when held in a strong light after vigorous shaking; but upon allowing the solutions to stand, and then drawing off samples for filling the viscometer from the upper level of liquid, stoppage of the capillary by dust particles was obviated.

Solutions.—Moderately concentrated solutions were made up by weight, and the concentrations in weight-percent were calculated to concentrations in mols per liter by means of tables of density. The more dilute solutions were made by measuring additional water into a measured volume of a more concentrated solution.

Densities.—Densities were interpolated from the International Critical Tables, (III, 92), as being of sufficient accuracy for the conversion of our moderately dilute solutions from a weight-percent basis to a mol-volume basis; and of more than sufficient accuracy for their use in viscosity measurement. Since our instrument is of the variable-pressure type, the density of the liquid enters only into a hydrostatic head correction (amounting to less than 0.1 percent of the total pressure) and into a kinetic energy correction (amounting to between 0.3 and 0.4 percent of the total pressure); an error in density of 3 percent will affect the precision of the viscosity measurements only 1 :10,000.

Data.—The experimental results are summarized in Table II. Three measurements of the viscosity of aqueous potassium ferrocyanide at 25° C. by Rankin and Taylor (8) are included for comparison.

TABLE II

SUMMARY OF EXPERIMENTAL DATA ON THE VISCOSITY AND FLUIDITY OF POTASSIUM FERROCYANIDE

No. of Runs	Conc. c	Density ρ	Viscosity η	$(\eta-1)/c$	$\sqrt{c}$	Fluidity φ	$(\varphi-1)/\sqrt{c}$	φ Calc. by Eq.	Δ φobs.$-\varphi$calc.	
						18°				
2	0 2334	1 0536	1 09385	0 402	0 4831	0 9142	—0 1776	0 9136	0 0006	
4	0.1556	1 0350	1.0615	0 395	0.3945	0 9421	—0 1469	0 9406	0 0015	
3	0 0934	1.0203	1 0399	0 427	0 3056	0 9616	—0 12555	0 9627	—0 0011	
2	0 0424	1 0085	1 0197	0 465	0 2059	0 9807	—0.0938	0 9814	—0 0007	
2	0 0222	1 0038	1 0112	0.5045	0 1490	0 9889	—0 0744	0 9893	—0 0004	
2	0.0111	1 0012	1 0063	0 568	0 1054	0 9937	—0 0594	0.9939	—0 0002	
2	0 0028	0 9992	1 0019	0 679	0 0529	0 9981	—0 0358	0 9978	0 0003	
7	0	0 9986	1 0000	. . . . . .	0	1 0000	. . . .	1 0000	0	$\Sigma\,\Delta\,i=0\ 0000$
										$\frac{\Sigma\,\lvert\Delta\,i\rvert}{N}=0\ 0007$
						25°				
	(0 5000)	. . . . . .	(1 2575)	(0 515)	(0.7071)	(0 79525)	(—0 2896)	0 7967	(—0 0014)	
	(0 2500)	. . .	(1 1173)	(0 469)	(0.5000)	(0 8950)	(—0 2100)	0 8948	(0 0002)	
3	0 2327	1 0515	1 1079	0 464	0.4824	0 9026	—0 2019	0 9017	0 0009	
3	0 1551	1 0332	1 0714	0 460	0 3938	0 9334	—0 1692	0 9327	0 0007	
	(0 1250)	. . . .	(1 9593)	(0.474)	(0 3536)	(0 9440)	(—0 1583)	0 9448	(—0 0008)	
3	0 0931	1 0187	1 0431	0 484	0 3051	0 95685	—0 1414	0.9579	—0 0010	
2	0 0423	1 0070	1.0232	0 5485	0 2057	0 9773	—0 1102	0 9792	—0 0019	
3	0 0222	1 0022	1 0120	0 5405	0 1490	0 9881	—0 0796	0 9881	0	
3	0 0111	0 9996	1.00635	0.572	0 1054	0 9937	—0 0599	0.9933	0 0004	
2	0 0055	0 9983	1 0033	0 600	0 0742	0 9967	—0 0444	0 9962	0 0005	
3	0 0028	0 9976	1 0018	0 642	0 0529	0 9982	—0 0340	0 9977	0 0005	
8	0	0 9970	1.0000	. . . .	0	1 0000	. .	1 0000	0	$\Sigma\,\Delta\,i=0\ 0001$
										$\frac{\Sigma\,\lvert\Delta\,i\rvert}{N}=0\ 0007$

NOTE: Bracketed values are taken from Rankin and Taylor for comparison.

INTERPRETATION OF RESULTS

When the values of $(\eta-1)/c$ were plotted as ordinates against the corresponding values of c as abscissas, (or preferably against the corresponding values of $\sqrt{c}$, since this effects a spreading of the points at low concentration) concave sagged curves were obtained which exhibited minima at about 0.18 mol per liter ($\sqrt{c} = 0.43$). While $(\eta-1)/c$ is strictly the slope of the chord connecting a point on the viscosity—concentration curve with the origin, it approximates the slope of the curve at that point; thus the initial downward slope of these curves corresponds to negative curvature in the $\eta - c$ curves, and the minimum to a point of inflection in the latter. These plots of the "Grüneisen function" emphasize that the negative curvature of the $\eta - c$ curve is more pronounced at the lower temperature; in accord with the expected behavior of electrolytes in aqueous solution (4a).

TABLE III

THE FLUIDITY AND VISCOSITY OF AQUEOUS POTASSIUM FERROCYANIDE

Concentration mols per liter	18°		25°	
	φ	η	φ	η
0 001	0 9989	1 0011	0 9989	1.0011
0 0025	0 9980	1 0020	0.9978	1 0022
0 005	0 9967	1 0033	0 9964	1 0036
0 01	0 9944	1 0056	0 9938	1 0062
0 025	0 9882	1 0119	0.9868	1 0134
0 05	0.9786	1 0219	0 9759	1 0247
0 1	0 9604	1 0412	0.9550	1 0471
0 25	0 9081	1.1012	0 8948	1 1176

When the values of $(\varphi - 1)/\sqrt{c}$ were plotted as ordinates against the corresponding values of $\sqrt{c}$ as abscissas, the points lay approximately along straight lines which intersected the axis of $(\varphi - 1)/\sqrt{c}$ at -0.0245. The equations of these lines were established as:

$$(\varphi - 1)/\sqrt{c} = -0.0245 - 0.3185\sqrt{c} \text{ at } 18^\circ \text{ C.}$$
$$(\varphi - 1)/\sqrt{c} = -0.0245 - 0.3720\sqrt{c} \text{ at } 25^\circ \text{ C.}$$

whence:

$$\varphi = 1 - 0.0245\sqrt{c} - 0.3185 c \text{ at } 18^\circ \text{ C.} \tag{3}$$
$$\varphi = 1 - 0.0245\sqrt{c} - 0.3720 c \text{ at } 25^\circ \text{ C.} \tag{4}$$

The fluidities calculated by these equations, and the deviations from the observed fluidities, are given in Table II.

The relative viscosities and fluidities of aqueous potassium ferrocyanide at round concentrations, as calculated by means of Eqs. (3) and (4), are given in Table III.

SUMMARY AND CONCLUSION

Measurements have been made on the relative viscosity of aqueous solutions of potassium ferrocyanide at 18° and 25° C. over the range of 0.003 to 0.223 mol per liter. Our values at 25° C. accord well with some earlier values recorded in the literature.

The stiffening effect on the solution due to the electric forces of the ions in tending to maintain a space-lattice structure has been observed. While the data necessary for the computation of the constant A by means of the equation of Falkenhagen and Vernon (2e) are not available to us, and we have not found in the literature any computation of this constant for $K_4Fe(CN)_6$; the observed value : $A = 0.0245$, compares favorably in order of magnitude with the value to be expected.

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GEOGRAPHY AND GEOLOGY OF KELLEY'S ISLAND

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HISTORY

After the turn of the nineteenth century, a few whites began to visit Kelley's Island for the purpose of trading, but at the outbreak of the war of 1812, they were driven away by the menacing attitude of the hostile Indians. General Harrison, then commanding the Army of the Northwest, stationed a guard on the west shore for the purpose of reconnoitering the movements of the British and Indians on the lake. The squadron of Commodore Perry lay for a time in the harbor south of the island, prior to its history-making engagement with the British north of Put-in-Bay. The successful outcome of the Battle of Lake Erie forced the Indians to flee the Island region. "Cunningham's Island," as it was originally known, after its first white trader (1803), did not become permanently settled until after 1833, when Irad and Datus Kelley acquired title to the whole island. For a hundred years, it has been called Kelley's Island.

Evidences of former Indian occupation are numerous. There are remains of earthworks on the Huntington property, inclosing an area of nearly seven acres. Most noted of all is Inscription Rock, which formerly bore deeply engraved pictographs on its glacially-smoothed surface. The wear of sightseers feet and the zeal of initial carvers has for the last decade rendered the inscriptions illegible. Inscription Rock measures approximately thirty feet long, twenty-one feet wide, stands ten feet above the water and is located at the water's edge of the south shore near Lay Bros. dock, where it has been separated by wave action from the main island mass of Columbus limestone. This famous Indian relic was discovered by Charles Olmstead, of Connecticut, in the year 1833, while on the island studying the glacial grooves. Its symbols were later authoritatively interpreted as depicting the occupation of this region by the Eries, the coming of the Wyandots, the final triumph of the Iroquois, and the flight of the Eries, who gave the lake its name.

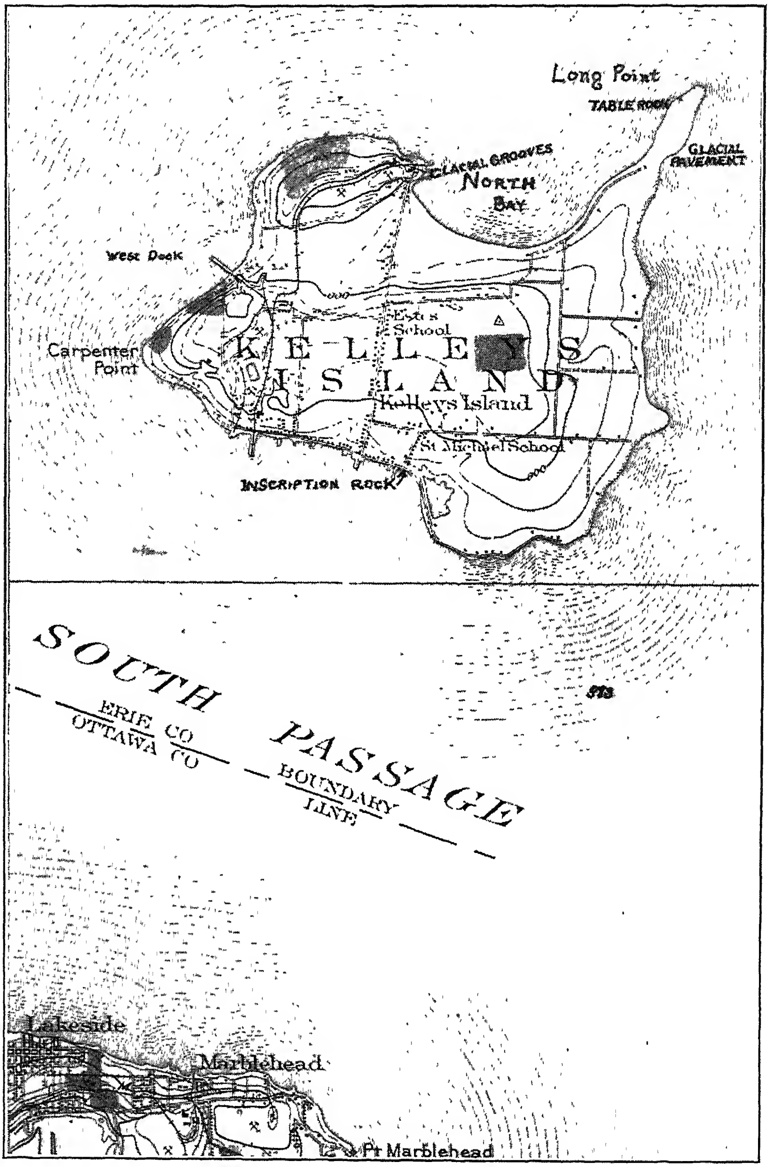

Fig. 1. Map of Kelley's Island

GENERAL DISCUSSION

This picturesque island lies three and one-half miles off the mainland of Marblehead on the Ottawa peninsula and nine miles directly north of the city of Sandusky. It is second in size to Pelee Island and the largest of the islands in Lake Erie, belonging to the United States. The island is widely known for its extensive limestone quarries and the glacial grooves on the promontory near the west shore of North Bay.

In outline, Kelley's Island may be readily described as possessing a marked resemblance to the continent of Australia (Fig. 1). Eighteen miles of predominantly rocky shoreline surrounds the twenty-eight hundred and eighty-eight acres of the island. A cobble-stone beach is characteristic but numerous other types of shoreline lend variety and beauty.

The west shore, and the south shore as far east as Inscription Rock, is a cliff generally six to seven feet high, fronted by a beach made up of limestone cobbles of various sizes. Nor far east of Inscription Rock there is a good example of a bay-mouth bar, on the crest of which the south shore road has been constructed. From this point eastward and along the east shore to within half a mile of the end of Long Point, the beach is composed of limestone cobbles with occasionally a few erratics; from this beach the island rises gently to the interior. The remaining portion of the east shore of Long Point is rocky, but without high cliffs or loose stone.

The east slope of Kelley's Island is a gradual rise from Lake Erie, the result of exposure to the full force of the southwestward moving ice mass, whereas, the lee slopes not exposed to the ice action are bordered by bold cliffs. The best illustration of this process is that of Long Point. The west shore is an almost continuous line of cliffs ten feet in height that have been protected from much of the direct force of the ice and increased in sharpness by the breaking off of huge blocks by weathering and wave action along the joints. The main joints trend N. 30° E. and are generally parallel to the shore. Table Rock is an example of a moderately sized block that has been separated from the mainland by wave erosion along joints; it has been undermined by wave action to such an extent that it is almost ready to topple into the lake.

The shore of North Bay, from a point south of the "L" in "Long Point" to the North Side quarry docks, is a stretch

approximately a mile in length, of the only sand beach on the island, except for a short stretch north of the West stone-loading dock. The northwest shore is bordered by bluffs that are the highest on the island.

PHYSIOGRAPHIC AND GLACIAL HISTORY

During Pliocene time, before the advance of the glaciers of the Pleistocene, Kelley's Island was a part of the mainland. The shallow depression now occupied by Lake Erie was the location of a large eastward-flowing trunk stream into which flowed tributaries from the north and south. The islands of Lake Erie, including Kelley's, were then the higher portions of the divides between the streams. The glaciers that later advanced over this section from the north and east scooped out the residual material in the stream valleys and to some extent added to the excavations that had been produced by the erosive force of the streams. The passages among the islands were finally created when Lake Erie arrived at its present level of 573 feet A. T. Because the Pliocene tributaries flowed generally northeast into the trunk stream and because the direction of dominant glaciation was from that general direction, the total effect of these two factors has been to produce the present-day, parallel, island passages that trend N. 80° E.

After the final withdrawal of the Wisconsin Ice Sheet, a lake was impounded between the glacier front to the north and the watershed on the south. As the ice-front melted to the northeast, lower outlets were uncovered causing the level of the lake to drop rapidly to the elevation of the new exits. During the successive stages of Lake Erie, known as, Lake Maumee, Lake Whittlesey, and Lake Warren, Kelley's Island remained submerged. During the Lake Lundy stage, a rectangular island of about one-third the size of the present one appeared. above the surface of the cold, glacial waters. The shore of this island is evident at various places, especially prominent a short distance north of Estes School, at an elevation of 610 feet A. T. Here are abandoned, water-worn cliffs seven to eight feet high, now partially overgrown with scrub growth, but yet conspicuous and bearing adequate testimony to the fact that the Lake Lundy stage must have been of long duration to have enabled the waters to nip out these prominent cliffs in the limestone rock of the island. Near Carpenter

Point and at other locations on the island this ancient shore-line may be observed at an elevation of thirty-seven feet above the present lake level.

The next lowering of the level of Lake Erie resulted in the emergence of the western end of the lake and the confinement of the water in the eastern half of the basin. This was the final stage in the shrinkage of the post-glacial lake. Since the removel of the ice from the area of eastern Canada, the land has gradually risen and tilted the Great Lakes to the southwest. The rise of the water level in western Lake Erie has produced estuaries at the mouths of the Maumee, Portage and Sandusky Rivers, the good harbors at Toledo, Port Clinton and Sandusky. If the present rate of tilting continues, Kelley's Island will probably remain an island for perhaps the next twenty-five hundred years, after which Niagara Falls may cease to be and the Great Lakes drain into the Mississippi River by way of the Illinois River and by way of the Maumee, Wabash and Ohio Rivers.

Professor E. L. Moseley, of the Bowling Green State Normal College[1] made a thorough study of the island region and arrived at the conclusion that the rise of the water for at least the last four centuries has continued with a nearly uniform rate of about two and one-seventh feet (2.14) a century. If this rate has been uniform, according to Moseley, approximately a thousand years ago the Indians may have walked from Sandusky to Kelley's Island at any season, it being necessary to swim across only one or two streams and wade through some marsh.

Glaciation has been the dominant factor in the physiographic history of Kelley's Island and evidence of its presence is everywhere conspicuous. The islands in western Lake Erie present some of the most marked indications of glacial erosion anywhere to be found in the United States. The grooves gouged by the glaciers on the rocky shores were noticed by the first settlers of Kelley's Island (Fig. 2) and new grooves are continually being uncovered during the course of removing soil for the extension of quarrying operations.

The prominence of glacial markings is due to the fact that the soft shales to the east offered little resistance to the glacier, but the harder limestones of the Cincinnati arch were a difficult barrier to the progress of the Erie lobe. The deepest grooves

[1]Moseley, E. L. "Formation of Sandusky Bay and Cedar Point," Ohio State Academy of Science, Vol. IV, Part V.

FIG. 2. (Upper.) Glaciated limestone pavement located on Long Point in the northeast portion of the island. Cross-sections of colonial corals, two to three feet in diameter, are exposed here.

FIG. 3. (Lower.) Kelley's Island glacial grooves, located at the old North Side Quarry, on the west shore of North Bay. This region is now a state park.

are found on the higher elevations of the island which were naturally more exposed to the leveling action of the ice.

Nearly all of these magnificent glacial grooves have fallen prey to the economic activity of man, and only near the northwest shore of the island may the huge gouges be seen today (Fig. 3). Here the State of Ohio has created (1931) a state park to preserve them for posterity. Unfortunately, the impress of the initial and name-chiseling vandal is too evident on the surface of these invaluable glacial carvings; since they became state property, additional names have been chiseled deeply into the grooves and further destroyed their beauty.

The Kelley's Island Glacial Grooves are located at the terminus of a line of bluffs overlooking North Bay and may easily be reached, from the steamboat dock at the foot of Division Street, by continuing northward across the island to the west shore of North Bay. The grooves are located at the edge of the old North Side quarry and were set aside by Mr. Younglove, former president of the Kelley Island Lime and Transport Company. A part of one of these grooves was acquired by the Western Reserve Historical Society of Cleveland and another portion may be seen in the National Museum at Washington, D. C. National interest in these grooves was first aroused by an excursion of the American Association for the Advancement of Science, while meeting in Cleveland, Ohio, in 1888. It is an inspiring geological phenomena—like so many Corinthian columns lying side by side. They constitute a convex surface that dips slightly (1°) S. 80° W. under four feet of overlying glacial till. Six distinct columns may be distinguished, but no two have the same size or degree of curvature. The largest is at the crest of the arched surface and is shaped somewhat like the modern steel or concrete burial vault; its crest is about five feet above the lowest groove. Chatter marks are very distinct. The columns are not all mathematically symmetrical, but in a few cases branch out or disappear. Occasionally some obstruction forced the tools of the glacier to deviate and scratch a shallow furrow at an angle to the parallel striae.

It is believed that the location of the grooves was originally the site of a small depression formed by preglacial water action, into which the ice crowded the granitic material which constituted the grooving-tool; the rasping, scratching, scraping and polishing went on concurrently and in increasing degree until

this enormous series of furrows resulted. Most of the Kelley Island grooves are straight, but some have been discovered by removal of the local till that are greatly curved and indicate the influence of preglacial or subglacial water action. There can be no doubt that there has been considerable erosion by direct action of ice, but the presence of cross-striae should warn the

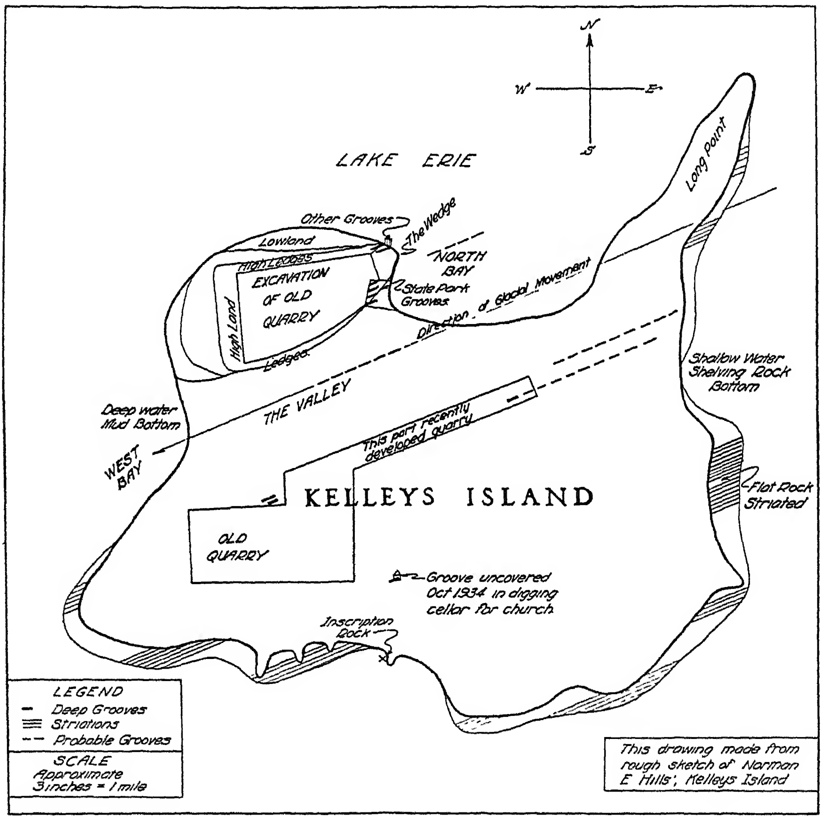

FIG. 4. Kelley's Island

geologist that the power of glacial ice to gouge out solid limestone must not be too strongly emphasized.

Four distinct, successive movements of glaciers, during the Pleistocene, are recorded by the direction of striae on the basement rock of Kelley's Island. Ice was first confined to the Lake Erie valley, but did not extend above and over the summit of the watershed to the south and consequently the lobe was

forced to move to the southwest, scooping out channels between the islands. The thickness of the ice was probably no greater than nine hundred and fifty feet. During the height of the glacial period the ice became thicker, extended over the divide of the watershed and moved from north to south, because the Illinois lobe then blocked the natural southwest outlet. The general southwest movement was resumed on the retreat of the ice front to the Lake Erie watershed and the withdrawal of the Illinois glacial lobe which blocked its path on the southwest. The markings of the previous north-south movement were obliterated on all eastward sloping rock surfaces, but on the lee side the north-south marks were protected. There was a feeble repetition of the north-south movement when the watershed no longer compelled a westerly movement. The evidence is faint, because the movement was not long continued.

On the east shore of Long Point opposite the end of the road, there is a glacial pavement of remarkable smoothness with shallow grooves plainly discernible, trending in the direction of S. 80° W. The width of this pavement varies from approximately one hundred and fifty to three hundred feet along the lake shore and is about five acres in area. The extent of the glacially-smoothed rock surface under the water of the lake is at least four times the area above water. The recency of the glacial period is strikingly shown by the sharpness of the chatter marks in the shallow grooves. This is remarkable when one considers the fierceness of the "northeasters" that beat upon this exposed shore. Nowhere on the island are there so many huge glacial erratics as lie here on the glacial pavement; many are four and five feet in diameter. Numerous and huge as are the erratics, the vast level sweep of the glacial pavement is hardly broken.

STRUCTURE AND LITHOLOGY

Kelley's Island is composed of the Columbus limestone of Middle Devonian age which is underlain by the Monroe limestone of the Upper Silurian. Since the highest elevation on the island is forty-eight feet above Lake Erie and the upper two feet of the Monroe is exposed below lake level in the quarries, all but the upper ten feet of the Columbus occurs on the island. This marks the most northerly outcrop of the formation in Ohio; here about sixty feet thick. The crest of the Cincinnati arch or geanticline is located about twenty miles

to the west and bends northeast across Lake Erie into Ontario. This is evident from the slight southeastward inclination of the Columbus strata; the dip is not noticeable in the sides of the quarries, but at the end of Long Point a local steepening is perceptible to the eye. The dip was found to be 6°, S. 40° E.

The North Side quarry is the oldest and deepest; there was an early demand for the massive grayish-brown limestone of the "bottom rock" used in breakwaters and other massive structures. An excellent view of the quarry may be obtained from the Glacial Grooves. The quarry section is readily divided into two parts, upper and lower. The upper part is a thin-bedded, fossiliferous, gray to bluish-gray limestone, about twenty feet thick which is slightly more massive toward the bottom. The lower part begins with the "bottom rock" stratum, a massive layer of brownish-gray limestone from seven to eight feet thick. The strata continues to be massive and more fossiliferous to the floor of the quarry, and is generally brown to grayish-brown with some chert layers of minor importance. The lower part of the Columbus limestone is about thirty-two feet thick which makes the total thickness of this formation in the quarry approximately fifty-two feet. One foot of the Monroe limestone has been penetrated and the important Middle Devonian-Silurian unconformity may be readily determined by the sharp faunal break, even though the Columbus and Monroe limestones are disconformable and appear to be one formation.[2]

The rapid falling off in demand for building stone and the increasing demand of crushed stone for lime, flux and road building has made it more economical to quarry only the thin-bedded upper part and some of the "bottom rock" of the Columbus. As a result almost the whole top of the island is being removed from west to east; the average depth of the vast quarry is twenty-five feet. The well-marked bedding planes and numerous joints make the upper part of the Columbus limestone easy to quarry. The abundance of cracks and joints may have been in part the result of subsequent uplifts of the Cincinnati arch; the majority of the vertical planes trend parallel to the axis of the arch which in this part of Ohio is in a direction of N. 30° E. The upper part of the Columbus is a very pure limestone and therefore valuable for

[2]C. R. Stauffer. "The Middle Devonian of Ohio," Geological Survey of Ohio, Fourth Series, Bulletin 10, p. 137.

use as lime and flux. Analyses disclose increasing proportions of magnesium carbonate and decreasing proportions of calcium carbonate from the top to the bottom. In the upper beds the amount of $CaCO_3$ is as high as 97% and the amount of $MgCO_3$ is as low as 2%, whereas the lower massive beds run as low as 78% $CaCO_3$ and as high as 20% $MgCO_3$. Alumina, iron oxide and silica make up the remaining 2%.

The Columbus limestone of Kelley's Island is very fossiliferous; corals are especially numerous. The most conspicuous are the huge colonial corals which occur in colonies from three to six feet in diameter. Excellent transverse sections of the corallites are exposed on the glaciated surfaces of the island. Individual horn corals may be easily found, of these are: *Cystiphylum Ohioense*, *Zaphrentis Wortheni* and *Zaphrentis Edwardsi*.[3] The Middle Devonian is noted for the huge fishes that swam in its seas and their fossilized remains are frequently found; the most important that have been recovered are the jaws of the *Onychodus*, which are a foot long and studded with sharp pointed teeth.

ECONOMIC

The Labradorian Glacier scraped all the residual soil from the rocky surface of Kelley's Island and deposited a shallow cover of glacial till that was thinned further by the waves of the shrinking Lake Erie. Over much of the area, grass barely clings to an inch or two of soil; nowhere is the island surface more than two and a half feet above solid rock. Such a thin covering of earth is difficult to cultivate and is more suitable for the growing of vineyards and fruit trees, especially so, since the soil is well charged with lime derived from the disintegration of the underlying rock. The success of grape culture also has been dependent on the equable lake climate that is notably free from late spring and early autumn frosts.

The cedar forests that originally covered the entire island were among the first sources of revenue for the early dwellers. So abundant was this beautiful wood that it supplied building material and fuel. The "Walk-in-the-Water," the first steamer to ply the waters of Lake Erie (1818), was supplied with fuel by the red cedar of Kelley's Island; this ship was wrecked in 1820 in a storm. The red cedar forests rapidly disappeared

[3]Geological Survey of Ohio, Second Series, Vol. II.

before the woodman's ax and today only a few trees are found scattered on the bluffs. The primeval forest was composed also of white oak on the high land, maples, hickory and hackberry on the lower and more level surface, and sycamore on the low marshy ground near the shore of North Bay. Only six acres were cleared in 1833.

Vines of the wild grape were abundant and large. The first cultivated variety was set out in 1842 from cuttings brought from Rockport, New York, but it was not until 1854 that there was a large increase in acreage. Some Germans who had come from the wine districts of the old world found employment on the island and realized its favorable climatic and soil conditions. The price of land then rose rapidly from fifty dollars to as high as one hundred and twenty-five dollars per acre. Grape rot did not appear until 1862 and for eighteen years no frosts harmed the grape crop. The wine industry increased until after the World War when the storage capacity of the Kelley's Island wine cellars was more than half a million gallons.

The residents derive considerable income from the summer tourists who are attracted by the fishing and quiet of the island. Commercial fishing is an important economic activity during the Spring and Fall. Fish abound on the nearby shoals and are caught in such quantities that the island region ranks high in the fresh water fish industry of the United States. The fish are brought to the island docks from where they are collected and transported to the large wholesale houses in Sandusky for shipment mainly to Chicago and New York markets.

Quarrying is the leading industry of Kelley's Island. Limestone was first quarried in 1833 on the north side and the first shipment was made from a pier on North Bay in the following year. Quarrying is easy and economical, because the loose, thin layer of soil may be rapidly removed from above the limestone. Quarries were later developed on the south and west sides, but today the north and south loading-docks are abandoned and all stone is dumped into freighters and barges from a modern elevated pier on the west shore. Much stone, well adapted for building purposes, was formerly sold, but this use has largely been abandoned and now all the limestone is crushed and sent to Cleveland, Buffalo and Gary for flux or to Duluth to be burned into lime. The Kelley Island Lime and Transport Company formerly burned lime on the island

and at Sandusky, until it was found to be more economical to burn the stone near the markets or the source of fuel supply. At one time sixteen lime kilns operated near the North Bay docks at a capacity of sixteen hundred barrels of lime per day. Cooperage shops were maintained at the time. The population of Kelley's Island during this period of great activity was more than a thousand, but has since decreased to six hundred and thirty-eight, according to the 1930 census. The new modern use for crushed stone in the manufacture of cement, tile and building blocks and the repeal of prohibition are new factors that will tend to aid the economic situation of Kelley's Island.

Antillean-Caribbean Geology

The first volume of Charles Schuchert's Historical Geology of North America concerns the stratigraphy and historical geology of the "Antillean-Caribbean Region, or the Lands Bordering the Gulf of Mexico and the Caribbean Sea." In this compendium the summary comes first. Here Schuchert considers the greater geologic features, diastrophism, and paleogeography. In section II are considered the ancient Caribbean Mediterranean, the Antillean Sea and the young Gulf of Mexico. Section III takes up the biogeography and presents the biogeographic evidence bearing on the problem. These three sections take up 113 pages. Section IV takes up in detail the lands. Here we find the geologic history of Mexico, Gulf Coastal Plain, Nuclear Central America, the Antilles, the young Isthmian link connecting Central and South America, Northern South America, and the Oceanic Islands. This is the major portion of the book covering some 654 pages.

It is impossible to do justice to this volume in the space available. Schuchert rejects the Wegenerian theory of continental drift and states that the "continuous linking of fold mountains does not exist in nature and the theory must be abandoned." He also does not believe in a land bridge, as do most zoogeographers, from Yucatan to Cuba and Hispaniola. He considers that the present Greater Antilles are fragments of a greater Central America. There was no land bridge between North and South America in the Permian (plants), Triassic (reptiles), or Jurassic (dinosaurs), but a land connection first appeared in late Cretaceous to early Eocene times. During late Eocene to middle Miocene it was broken by flooding as it was in early Pliocene. From middle Pliocene to the present it has not been broken. In pre-late Eocene times Central America continued eastward forming a long Antillean peninsula reaching to the Virgin Islands and The Banks. The paleogeography is illustrated by a series of 16 maps showing the changes from Middle Pennsylvanian to upper Pliocene-Pleistocene. There are geological maps for most of the areas discussed. Needless to say, these are small scale and show the distribution only of the larger divisions of the rocks. They are for the most part taken from available sources, some unfortunately being fairly old, as no newer ones are available. There is a good bibliography at the end of each section which gives the important papers on the various regions. An extremely complete index winds up the volume.

Although the reviewer does not entirely agree with Dr. Schuchert in his interpretation of some of the evidence, he can heartily recommend this book. It brings together the geology of the region around the Gulf of Mexico and the Caribbean Sea, making it available in one volume. This is very convenient for graduate students and those who handle advanced courses in geology. We wish the book success.—WILLARD BERRY.

Historical Geology of the Antillean-Caribbean Region, by Charles Schuchert. xxvi+811 pp. New York, John Wiley and Sons, Inc., 1935.

THE ALIMENTARY CANAL OF THE ORIENTAL FRUIT MOTH LARVA

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The oriental fruit moth, *Grapholitha molesta* Busck, was first found in Ohio in 1925 but spread rapidly throughout the State and has now become the major peach pest. Although the literature dealing with this insect has become voluminous, so far as the writer is aware, practically nothing has been published on the internal morphology of the insect. It seemed desirable, therefore, that such a study be undertaken.

The writer has been engaged in a study of the biology and control of the oriental fruit moth at the Ohio Agricultural Experiment Station for a number of years and, consequently, had an abundance of live material available. Fresh material, consisting of full-grown hibernating larvae, was used in all dissections. The larvae were killed in hot water and dissected either in saline solution or in tap water. The stains used in the preparation of slides were limited chiefly to Haemalum and Fast Green FCF—Haemalum for nuclei and Fast Green for cytoplasm and cell walls.

The larva of the fruit moth, as well as the other stages of the insect, has been described by Garman (1), Peterson and Haeussler (4), and Stear (5); consequently, no further description will be included here.

The position of the different parts of the digestive tract in relation to the body segments varies with the degree of extension of the body. The description given here is that of the digestive tract of a larva in which the body segments are partly extended.

Gross Anatomy of the Digestive Tract

The alimentary canal of the oriental fruit moth is a straight tube extending from the mouth to the anus (Fig. 1). The fat-body forms a sheath almost completely surrounding the tract and apparently supports

Note: This study was begun at Ohio State University in a course on "The Morphology and Development of Insects," given by Dr. C. H. Kennedy. The writer desires to express his appreciation to Dr. Kennedy for his suggestions and criticisms.

it to some extent. The canal is constricted locally, and the three main divisions—the fore-intestine, mid-intestine, and hind-intestine—are rather easily distinguished. The various parts of these divisions are not very evident from a superficial examination.

FORE-INTESTINE, SALIVARY GLANDS, AND SILK GLANDS

The pharynx, which is very small, is located within the head. Arising from the pharynx are bundles of muscles attached to the head capsule.

Two salivary glands open separately into the mouth beside the pharynx. These glands consist of two long, coiled tubes, one on each side of the alimentary canal, which lie in folds chiefly in the region of the thorax. The anterior end, which lies very close to the pharynx, becomes exceedingly small and is closely enclosed in muscles.

The silk glands also consist of two tubes, one lying on each side of the digestive tract. The two tubes are similar and extend, with many convolutions, in a caudal direction as far as the fourth abdominal segment. They lie in folds in the adipose tissue and, when fully extended, are approximately as long as the body of the larva. The two tubes become smaller anteriorly and join together in the head on the ventral side of the pharynx. They become very small at this point and were not traced further.

A slight constriction in the alimentary canal back of the head indicates the beginning of the oesophagus. There is no apparent distinction between the oesophagus and crop. At approximately the middle of the metathorax a distinct, abrupt enlargement indicates the beginning of the mid-intestine.

MID-INTESTINE

The mid-intestine, which constitutes more than half of the entire length of the alimentary canal, continues without much change except a slight decrease in diameter from the metathorax to the sixth abdominal segment. A distinct enlargement in this segment indicates the pyloric valve and the beginning of the hind-intestine.

HIND-INTESTINE

The attachment of the malpighian tubes just posterior to the pyloric valve also marks the beginning of the small intestine. These tubes arise in two small pouches or bladders (Figs. 1 and 7), one on each side of the anterior end of the ileum. These pouches apparently are structures about which little is known. Similar pouches have been figured, however, by Peterson (3) for the tomato worm, *Protoparce sexta* Johan. One tube arises from each pouch and extends anteriorly a short distance to approximately the anterior end of the sixth abdominal segment, where each tube divides. The four tubes then continue in a cephalic direction along the walls of the mid-intestine to the anterior portion of the fourth abdominal segment. At this point one tube on each side divides again, forming six tubes. These turn abruptly and, with many convolutions, follow caudad along the walls of the alimentary canal to the rectum. All of the six tubes enter the walls of the rectum.

The ileum is a narrow, straight tube extending to the posterior portion of the eighth abdominal segment. A slight stricture followed by a bulb-like enlargement indicates the colon, which is short. The rectum appears as a distinct enlargement just posterior to the colon.

Histology of the Alimentary Canal

FORE-INTESTINE

A histological examination of the fore-intestine revealed no unusual structures. The chitinous inner lining, or intima, is prominent and in the proventriculus, chitinous teeth are very evident (Fig. 3). Cell walls in the epithelium were not distinct in the slides prepared, but nuclei were prominent. Longitudinal muscles appear in isolated strands inside a continuous layer of circular muscles. The circular muscles are large, as shown in Figures 2 and 3.

The oesophageal valve is well developed and marks the division between the fore- and mid-intestine.

MID-INTESTINE

In the mid-intestine the cells of the digestive epithelium apparently vary in size and shape, depending upon their physiological condition at the time the insect was killed. In most of the specimens studied the cells were long and narrow as shown in Figure 4, and the inner edge indicated holocrine secretion. In a few specimens the cells were short and gave little evidence of a broken or striated border. The nuclei are prominent and usually lie near the base of each cell. The muscles are much smaller than in the fore-intestine, and the longitudinal muscles lie in strands outside the continuous layer of circular muscles. The longitudinal muscle strands are much more numerous than in the fore-intestine and occur at regular intervals around the stomach.

HIND-INTESTINE

The hind-intestine, as mentioned previously, is marked anteriorly by the pyloric valve and the attachment of the malpighian tubes. The pyloric valve (Fig. 6) consists of long, fan-shaped epithelial cells.

The cells of the malpighian tubes are large and spongy, with the inner border distinctly striated (Fig. 11). An enlarged section of one of the pouches in which the tubes arise is shown in Figure 7. The walls contain a distinct muscular layer and the epithelium of the ileum apparently extends into the pouch.

The ileum in cross section appears similar to the oesophagus. The circular muscles are large and the inner lining is prominent.

The colon, as shown in Figure 8, is apparently a bulb-like enlargement of the hind-intestine and is marked by large circular muscles.

A cross section of the rectum (Figs. 9 and 10) shows a continuous row of malpighian tubes inside the walls. The tubes lie between the epithelial tissue and a double, thin membrane which has been described by Ishimori (2). However, Ishimori described two rows of malpighian vessels inside the walls of the rectum in Lepidopterous larvae, but the writer has been able to distinguish but one in the fruit moth.

The chitinous inner lining of the rectum is prominent, and the longitudinal muscles appear in large isolated strands outside of the layer of continuous circular muscles.

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EXPLANATION OF PLATES

Plate I

Fig. 1. Diagrammatic dorsal view. Salivary gland and malpighian tube pulled out of position to show approximate length

Fig. 2. Cross-section through the oesophagus

Fig. 3. Cross-section through the lower end of the oesophagus or proventriculus showing the chitinous teeth.

Fig. 4. Cross-section through the mid-gut.

Plate II

Fig. 5. Cross-section through the ileum, or small intestine

Fig. 6. Longitudinal section through the pyloric valve showing a pouch from which the malpighian tubes arise.

Fig 7. An enlarged longitudinal section through a pouch or bladder.

Fig. 8 Longitudinal section through the colon and rectum.

Fig. 9. Cross-section through the rectum

Fig. 10. An enlarged portion of a cross-section through the rectum, showing the row of malpighian tubes.

Fig 11. Cross-section through a malpighian tube.

SYMBOLS USED IN PLATES

BL. ....Bladder of malpighian tube.
C. M. ...Circular muscle.
COL . Colon.
C. TIS. .Connective tissue.
EPI.... Epithelium.
H. I.....Hind-intestine.
IL .....Ileum.
INT ....Intima, or inner chitinous lining.
L. M.. .Longitudinal muscle.
M. I ..Mid-intestine.
M T ..Malpighian tube.
OES .. Oesophagus.
PH . . .Pharynx.
P V ....Pyloric valve.
REC . Rectum.
S. B .. .Striated border.

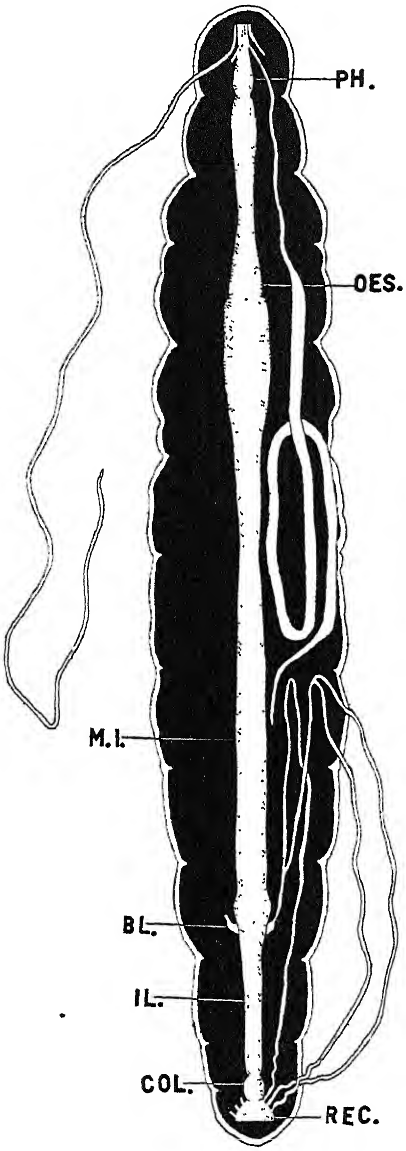

FIG. 1

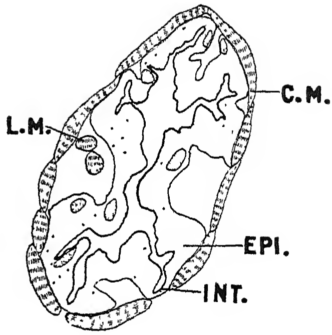

FIG. 2

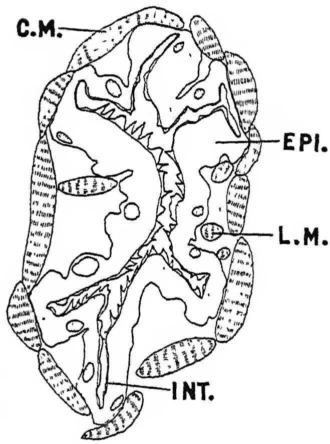

FIG. 3

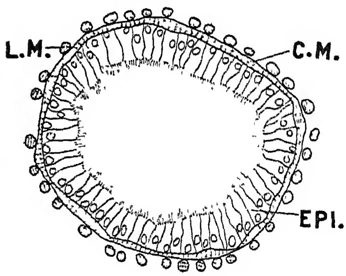

FIG. 4

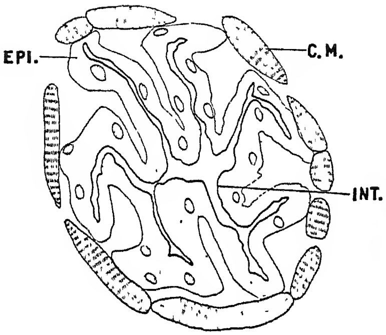

FIG. 5

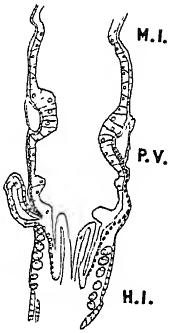

FIG. 6

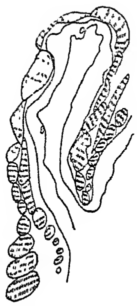

FIG. 7

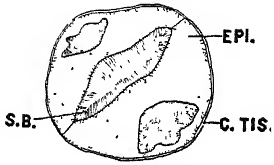

FIG. 11

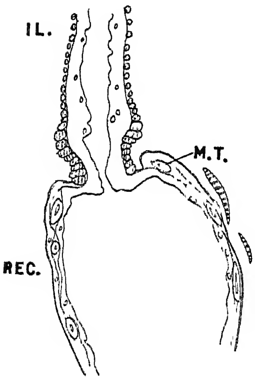

FIG. 8

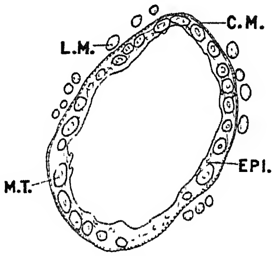

FIG. 9

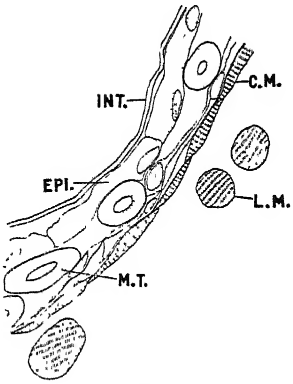

FIG. 10

THE EXTERNAL MORPHOLOGY OF HYDROUS TRIANGULARIS (HYDROPHILIDAE: COLEOPTERA)

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INTRODUCTION

The water-scavenger beetles live upon decomposing vegetable matter. They are found in the shallow water of quiet lakes and ponds, among the plants growing on the bottom. This study was made principally at the Franz Theodore Stone Laboratory of Ohio State University at Gibraltar Island, Put-in-Bay, Ohio. The greater part of the work was done with preserved material. One specimen was taken in a quiet pool on the shore of North Bass Island.

Hydrous triangularis is one of the larger species, having a length of 35 to 39 mm. and a maximum width of 14 to 17 mm. This genus is found in all parts of the United States and contains some of the largest and smallest members of the family.

The nomenclature used by the writer is adapted from the literature of such entomologists as Snodgrass, Korschelt, Imms and others.

This study was suggested by and made under the direction of Dr. C. H. Kennedy, of the Ohio State University, to whom the writer wishes to express sincere thanks for his many helpful criticisms and suggestions.

THE HEAD

(Pl. I, Figs 1 to 11)

The head capsule is rounded and about as long from the occipital foramen to the anterior margin of the labrum as it is wide between the eyes. The frontal sutures extend diagonally from the anterior margin of the eyes to the coronal suture which divides the vertex longitudinally. The head is normally partly withdrawn into the prothorax. The dorsal part of the vertex and clypeus are coarsely punctate. (Pl. I, Fig. 1).

The mouth-parts are in front of the head and the head is dorsoventrally flattened. The ventral wall of the hind part of the head is formed by the gula, which extends from the occipital region to the submentum The gula is elongate and is bounded laterally by the

gular sutures. The surface of the gula is separated from that of the submentum by a dividing suture. (Pl. I, Fig. 10.) A definite mentum is present. (Pl. I, Fig. 3.) In the grasshopper and other more primitive insects, the head is antero-posteriorly compressed and the mouth-parts are beneath the head. In the grasshopper a sclerite corresponding to the gula is not present, because of the short distance between the base of the submentum and the cervix.

The mandibles have five teeth and a retinaculum is prominent as a soft semicircular shelf between the premolar and molar regions. (Pl. I, Fig. 7.) The galea, digitus and lacinia of the maxillae are profusely marginate with long hairs. A prominent palpifer and subgalea are present and from the former arises the six-jointed palpus. A basal piece or cardo is present. (Pl. I, Fig. 4.) The labium bears two four-jointed palps, between which are the paraglossae. (Pl. I, Fig. 10).

The lamellate antennae are nine-jointed and are attached to the ventral side of the head between the eyes and the bases of the mandibles. (Pl. I, Fig. 11.) Attached to each lateral margin of the head is a large compound eye. These constitute a large part of the surface of the head.

The tentorium (Pl. I, Fig. 3) is braced in the occipital region by two posterior tentorial arms. Each dorsal arm of the tentorium arises from the sides of the body of the tentorium, between the anterior and posterior arms. These support the dorsal part of the head in the region of the antennal sclerite. Each anterior tentorial arm opens on the head posterior to the mandible.

THE PROTHORAX

(Pl. I, Fig. 9)

The anterior margin of the prothorax as seen from below is concave and the posterior and lateral margins convex. It is about half as wide along the anterior margin as it is along the posterior margin. The dorsal side is entirely covered by a plate-like pronotum. (Pl. I, Fig. 9.)

On the ventral side are two large propleural plates. (Pl. I, Fig. 9.) Anteriorly these extend from the pronotum to the lateral margin of the precoxal-bridge, (Pl. I, Fig. 9), and posteriorly as a narrow point projecting mediad back of the coxal cavity. The coxal cavities are between the median projections of the propleural plates and the lateral arms of the precoxal-bridge.

The legs of the water-scavenger beetle readily distinguish it from the predacious diving-beetles. Those of the former are equidistant whereas the middle and hind pair of legs are widely separated in the latter. In the male of *Hydrous triangularis*, the fifth joint of the tarsus has a cushion-like enlargement on the inner side called the empodium. The female tarsus consists merely of five normal joints.

THE MESOTHORAX

(Pl. II, Figs. 12, 13, 15, 16)

The meso- and metathorax are very closely connected and give the appearance of a single unit. The mesothorax is the shortest of the three thoracic segments. The largest area of the mesonotum is occupied by a smooth triangular plate, the prescutum. (Pl. II, Fig. 12). The

extreme anterior corners of the prescutum are produced into two hooks or clavicola. From the antero-lateral margins of the prescutum arise the articulations of the elytra. The articular sclerites of the elytra are not shown. The metepisternum and mesopleurum are united dorso-anteriorly by the mesopleural suture. (Pl. II, Fig. 13.)

On the ventral side the largest area of each mesopleurum is occupied by the episternum. This is an elongate sclerite that lies antero-lateral to the basisternum. The episternum and epimerum are divided obliquely by the pleural suture, the lower end of which articulates with the coxa. Meeting the upper end of the pleural suture at right angles is another suture that divides the episternum into supra- and infra-episterna. (Pl. II, Fig. 15.) Extending the length of and beyond the meso- and metathorax is a median spine-like structure, the sternum. This is crossed at the base of the mesothorax by a fine suture. Internally the furca (Pl. II, Fig. 16) arises as two median apodemes. These are connected immediately anterior to the coxae by a furcal ridge. Each branch of the furca is continued at its apical (anterior) end in two free distal arms. One arm extends antero-laterally beneath the episternum, the other as a lateral extension beneath the epimeron.

THE METATHORAX

(Pls. II and III, Figs. 12 to 17)

Posterior to and below the prescutum of the mesothorax is a median groove which lies between the scuto-scutellar sutures. (Pl. II, Fig. 14.) These extend the entire length of the scutum. The scutum is bounded anteriorly by two antero-lateral projections of the scuto-scutellar suture and laterally by the articular processes of the wings. These projections of the scuto-scutellar suture and the articular processes of the wings mark the anterior limit of the metathorax. The articular sclerites of the wings are not shown. Anterior to the metathoracic coxa and on the dorsal surface under the outer edge of the folded wing is a narrow triangular sclerite, the metapleurum. (Pl. II, Fig. 13.) This narrows anteriorly and is connected with the metepisternum by the metapleural suture (Pl. II, Fig. 13), which lies parallel to and just dorsal of the lateral edge of the metathorax. A continuous and definite suture between meso- and metathorax is not present. The prescutum is only loosely connected with the scutum. Medially the connection consists of a transparent membrane, laterally the pleural hooks (Pl. II, Fig. 12) are fused with the lateral margin of the scutum by a membranous structure.

Internally a Y-shaped apodeme, the metathoracic furca (Pl. II, Fig. 16), supports the metathorax. The base of this process arises between the metathoracic coxae. This median apodeme extends dorso-anteriorly toward the metanotum. A short distance below the metatergum arise the two arms.

On the ventral side, the metasternum and episternum are divided by a heavy suture. The episternum is similar to that of the mesothorax except there is no suture dividing it into supra and infra-episterna. The epimeron is not seen from below but is a narrow oblong structure attached to the lateral margin of the episternum and lies

on the dorsal edge of the metathorax. The metathoracic coxa (Pl. II, Fig. 15) has the appearance of another thoracic sclerite. Its ventral surface appears in the form of a flattened elongate plate which extends diagonally from the posterior end of the metapleural suture mediad and caudad to the sternal spine. The coxa is attached along the posterior margin of the metathorax. The attachment is such as to give it a restricted hinge-like movement. Inserted between the posterior edge of the wing of the metasternum and the anterior edge of the coxa is a narrow plate which is probably a much elongate trochantin (Pl. II, Fig. 14) which articulates with the coxa at its inner end. The peculiar structure of the coxa is a distinguishing characteristic of the family.

The wings are membranous and are normally folded beneath the elytra. The venation (Pl. III, Fig. 17) is much reduced. As in the Cantharid (Imms' Ed. 3, Fig. 469, p. 484, 1934) type M_1 and M_2 coalesce distally forming a very definite loop. From the point of junction M_2 is continued to the wing margin. The four anal veins and the first cubitus are distinct. Cubitus two is present but much reduced. The costal and radial veins are clearly seen near the costal margin.

THE ABDOMEN

(Pl. III, Figs. 18 and 19)

There are nine more or less cylindrical segments in the abdomen. The dorso pleural line (Pl. III, Fig. 19) divides the heavily chitinized hypopleurites from the membranous epipleurites. The pleuro ventral line is seemingly an evaginated rounded suture separating the hypopleurites from the sternal plates. Implanted in the membranous epipleurites are eight spiracles (Pl. III, Fig. 18). This number corresponds to the number of epipleurites.

Tergites 1, 2, 3, 4, 5, and 6 are normally covered by the elytra, and appear as tough membranous structures due to a reduction of the chitinization. The seventh and eighth tergites are normally exposed beyond the end of the elytra and are heavily chitinized. The ninth is usually withdrawn under the eighth tergite. The intersegmental membrane of tergites one and two has been obliterated by a definite fusion of these segments. Tergite ten, if present, cannot be differentiated from the ninth.

It is very likely that the first visible sternite contains elements of more than one abdominal segment but they are not indicated by sutures or lines. Five ventral plates or sternites are visible on the abdomen. The first three anterior plates are apparently fused and sternites eight in the female and sternites eight and nine in the male are normally withdrawn within the seventh. The first sternite is produced medially into a short process called the intercoxal process. This extends anteriorly between the metacoxae.

THE MALE GENITAL ORGANS

(Pls. III and IV, Figs. 20, 22, 23, 24)

The ninth sternum is present in the male. A membranous genital chamber arises within the ninth segment. The anus opens beneath the posterior end of the ninth tergite. (Pl. IV, Fig. 23.) The ninth

sternum (Pl. IV, Fig. 23) is extended posteriorly forming a single supporting structure for the genital chamber. Snodgrass (Smith. Misc. Coll., Vol. 85, p. 91, 1931) believes that the movable claspers or parameres (Pl. IV, Fig. 22) are homologous with the styli of the female. Between the two heavily chitinized parameres is a median intromittent organ, or penis. (Pl. IV, Fig. 22.) The penis is a membranous tubular structure bearing the opening of the ejaculatory duct or gonopore at its extremity. The gonopore opens ventrally. A chitinous median plate called the dorsal median strut extends along its dorsal surface. A similar but smaller ventral median strut extends along the ventral surface of the penis. A pair of basal plates underlap the anterior ends of the parameres. The basal plates arise behind the ninth sternite. They are united by the pons basalis into a single V-shaped structure. (Pl. IV, Fig. 24.)

Immediately anterior to the proximal end of the penis is the seminal vesicle. (Pl. III, Fig. 20.) This appears as a ball-like widening of the ejaculatory duct. Anteriorly the seminal vesicle is continued as a narrow tube to which the accessory glands are joined ventrally. In the region of these glands arise the vasa deferentia. Each vas deferens forms the outlet for a testicular tube.

THE FEMALE GENITAL ORGANS

(Pls. III and IV, Figs. 21, 25, 26, 27)

In the female the sternum of the ninth segment appears to be absent. The ninth tergite consists laterally of two narrow lateral projections and medially of a triangular sclerite. (Pl. IV, Fig. 25.) The appendages of the eighth and ninth segments are remotely similar to those of the orthopteran insects. This generalized structure of the genitalia suggests a primitive structure. These genital appendages are absent or rudimentary in many groups of insects, but their wide distribution throughout the orders leaves little doubt of their being primitive structures. The first valvulae are short pointed projections that are supported by two basal plates or valvifers. (Pl. IV, Fig. 27.) Antero-dorsal to the first valvifers are two lobe-like structures, the second valvifers. The second valvulae are absent. The second valvifers are the basal plates of the third pair of valvulae. The third valvulae consist of a long pair of blades each of which is provided with a distal stylus. These appendages of the eighth and ninth segments of the abdomen are potentially gonopods because of the association of the genital openings with these segments. The gonopore opens in the region between the second valvifers. (Pl. IV, Fig. 27.) The anal opening is immediately beneath the ninth tergite. (Pl. IV, Fig. 27.)

Internally a large sac-like structure extends into the eighth segment. (Pl. III, Fig. 21.) This is continued anteriorly as the seminal receptacle, and posteriorly as the bursa copulatrix. Opening into the bursa copulatrix is the vagina which connects with the paired oviducts. Each ovary is composed of three separate egg-tubes or ovarioles.

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EXPLANATION OF PLATES

External anatomy of *Hydrous triangularis* Say

PLATE I

FIG. 1. Head, dorsal view. FIG. 2. Head, ventral view. FIG. 3 Inside view of head showing tentorium from dorsal side. FIG. 4. Dorsal view of left maxilla. FIG. 5. Ventral view of left maxilla. FIG. 6. Ventral view of right mandible. FIG. 7. Lateral view of right mandible. FIG. 8. Dorsal view of right mandible. FIG. 9. Ventral view of prothorax. FIG. 10. Labium, ventral view. FIG. 11. Dorsal view of left antenna.

PLATE II

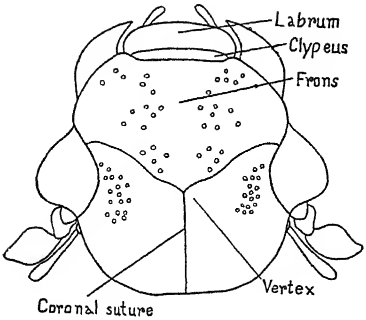
FIG. 12. Mesothorax, dorsal view. FIG. 13. Meso- and metathorax, dorsal view. FIG. 14. Metathorax, dorsal view. FIG. 15. Ventral view of meso- and metathorax. FIG. 16. Internal view of meso- and metathorax, showing furcae, dorsal side removed.

PLATE III

FIG. 17. Left wing, ventral view. FIG. 18. Dorsal view of abdomen. FIG. 19. Lateral view of abdomen. FIG. 20. Male reproductive system. FIG. 21. End segments of abdomen showing female reproductive system.

PLATE IV

FIG. 22. Dorsal view of postabdomen of male, abdominal segments 8 and 9. FIG. 23. Lateral view of postabdomen of male, abdominal segments 8 and 9. FIG. 24. Ventral view of postabdomen of male, abdominal segments 8 and 9. FIG. 25. Dorsal view of postabdomen of female, abdominal segments 8 and 9. FIG. 26. Ventral view of postabdomen of female, abdominal segments 8 and 9. FIG. 27. Lateral view of postabdomen of female, abdominal segments 8 and 9.



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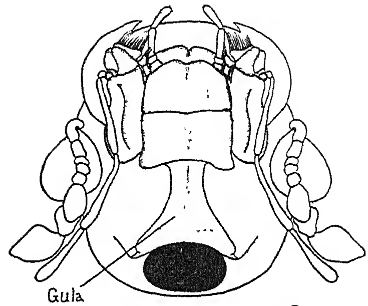

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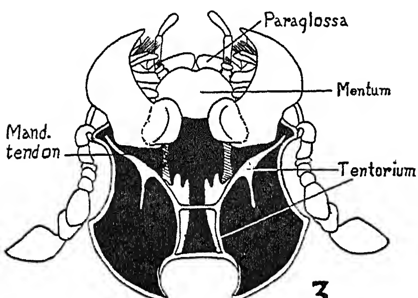

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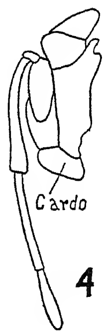

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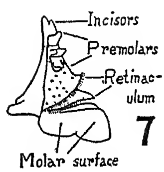

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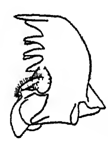

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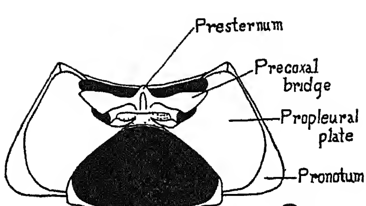

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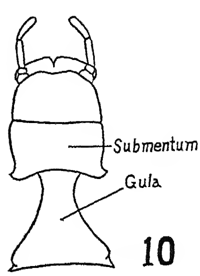

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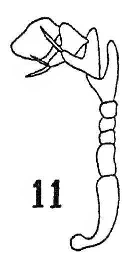

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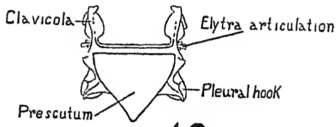
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Pleural hook
Prescutum

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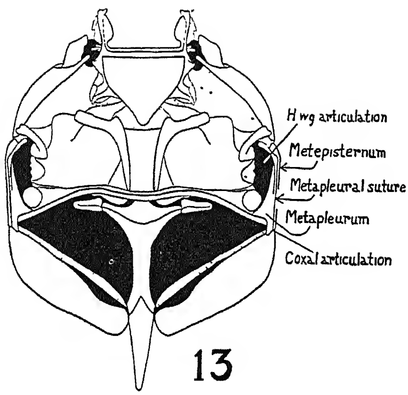
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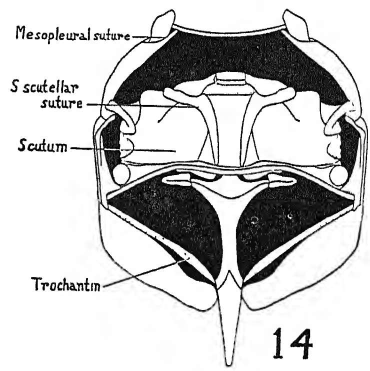
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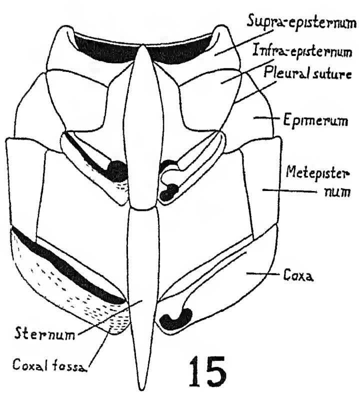
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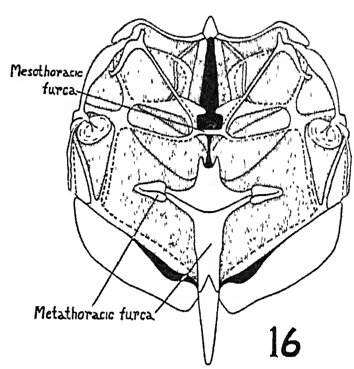
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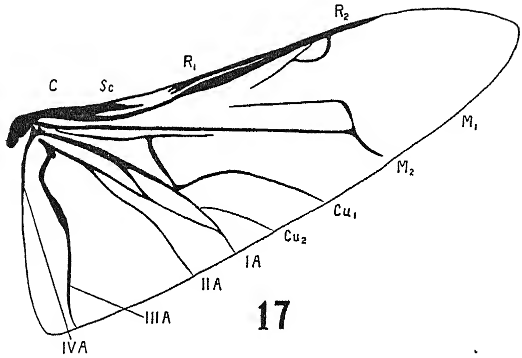
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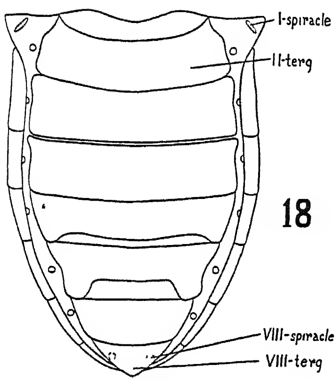
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II-terg
VIII-spiracle
VIII-terg

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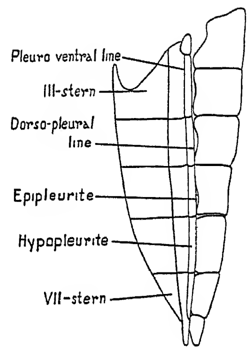
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III-stern
Dorso-pleural line
Epipleurite
Hypopleurite
VII-stern

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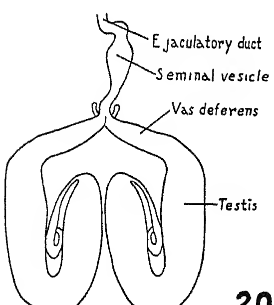
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Seminal vesicle
Vas deferens
Testis

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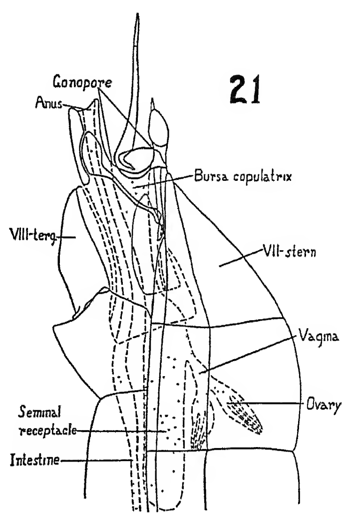
Gonopore
Anus
Bursa copulatrix
VIII-terg
VII-stern
Vagina
Ovary
Seminal receptacle
Intestine

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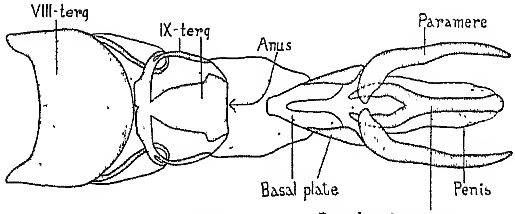

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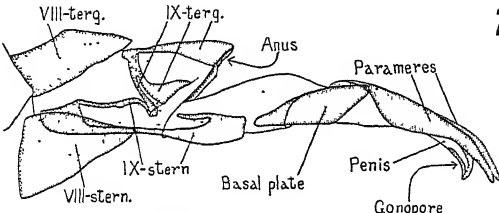

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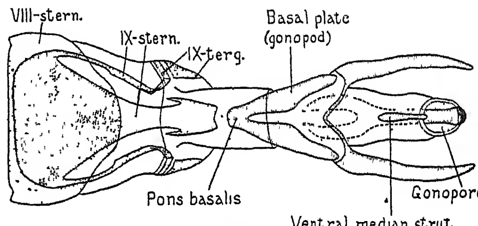

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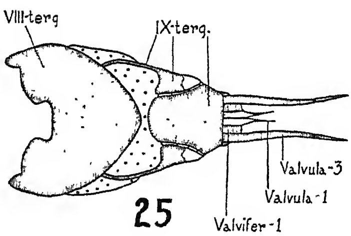

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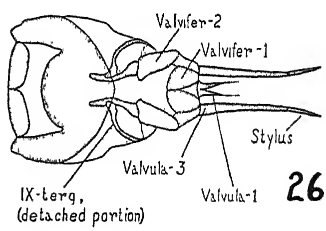

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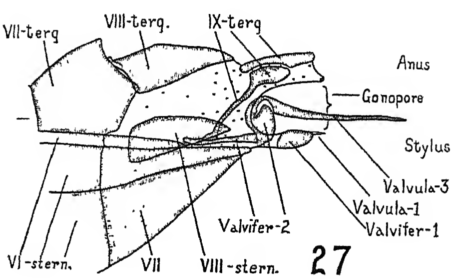

27

NEW RECORDS OF OHIO DRAGONFLIES (ODONATA)

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The latest complete list of Ohio dragonflies (Kellicott, 1899) lists 99 species. Since that time new records have been added by various workers, the last published records (Borror, 1930) bringing the list up to 116. During the last few years eleven new records for the state have been obtained, some of which are of unusual interest.

The new records for the state are as follows:[1]

117. *Lanthus albistylus* Hagen. Loudonville: 1♂, 3♀, and 6 exuviae June 6, 1915, J. S. Hine (DZE). Although these specimens were taken a number of years ago, the records were never published. This is an eastern species, and apparently has never been taken this far west before.

118. *Gomphus ventricosus* Walsh. Big Darby Creek, Harrisburg: 1♂ May 23, 1930, D. J. Borror.

119. *Cordulegaster diastatops* Selys. Cedar Swamp, Urbana: 14♂ June 12, 1926, and 1♀ June 7, 1927, J. S. Hine (OSM); 2♂ June 9, 1929, C. H. Kennedy (DZE); 2♂ and 1♀ June 6, 1931, 1♂ June 3, 1933, and 1♂ June 11, 1934, D. J. Borror. Eden Twp., Licking Co.: 1♂ July 6, 1931, M. D. Neiswander (OSM). Wakatomika Creek, Licking Co.: 1♂ May 21, 1932, and 1♀ May 30, 1934, D. J. Borror. Portage Co.: 1♂ July 7, 1935, J. A. Strasburg (in coll. D. J. Borror). This is an eastern species, but has been taken in Michigan and western Pennsylvania (Fraser, 1929), and in Indiana (Williamson, 1917, and Montgomery, 1930).

120. *Cordulegaster maculatus* Selys. Cantwell Cliffs, Hocking Co.: 1♂ June 14, 1925, C. H. Kennedy (DZE). Clear Creek, Hocking Co.: 1♀ June 17, 1931, J. S. Thomas (OSM); 1♂ and exuvium June 2, 1934, D. J. Borror.

121. *Somatochlora tenebrosa* Say. Byer, Jackson Co.: 2♀ July 1, 1934, C. F. Walker (OSM). Cedar Swamp, Urbana: 6♂ and 2♀ July 27, 1935, D. J. Borror. The specimens taken by Mr. Walker were two of several seen flying in a clearing near a small stream about a mile east of Byer. Those taken at Cedar Swamp were flying low over small pools in the open part of the swamp, and were fairly easy to capture.

[1]The location of the specimens listed in this paper is indicated in parentheses following the name of the collector, e. g., DZE, the collection of the Department of Zoology and Entomology, Ohio State University; OSM, the collection of the Ohio State Museum. All specimens collected by the writer, except several duplicates of *Sympetrum ambiguum* which were sent to the Museum of Zoology at Ann Arbor, Michigan, are in the writer's collection.

Although this is only the second species of *Somatochlora* to be found in Ohio, it is probable that other species also occur here. Walker's distribution maps (Walker, 1925) suggest that *williamsoni* Walker and *linearis* Say may also occur in Ohio.

122. *Erythrodiplax umbrata* Linnaeus. Cedar Swamp, Urbana: 1♂ June 11, 1934, D. J. Borror. This is a very unusual record. *E. umbrata* is a neotropical species, ranging normally from northern Argentina to southern United States. The most northern records hitherto reported are Georgia (Hagen, 1861) and Woods Co., Oklahoma (Bird, 1932). This specimen was taken in a cedar bog, a relic of post-glacial times, certainly a type of habitat in which one would least expect to find a tropical species. The specimen is entirely black and fully adult; the wing-band is black and extends from the nodus to the middle of the stigma, as is the case with most of the specimens from Mexico and Central America. In specimens from South America the wing-band tends to be shorter, frequently not reaching the proximal end of the stigma. This specimen was taken in the same swing with a male of *Cordulegaster diastatops*.

It might be of interest to note in this connection that I have just received from Mr. B. Elwood Montgomery, of Lafayette, Indiana, two specimens of *E. umbrata* collected by him in southern Indiana: 1♂ Gibson Co., September 1, 1934, and 1♀ (heterochromatic) Pike Co., September 1, 1934. Both specimens are quite teneral, suggesting that this species has bred in southern Indiana during the past season.

123. *Erythrodiplax minuscula* Rambur. Lake Alma, Vinton Co.: 1♂, June 23, 1933, D. J. Borror. This is also a neotropical species, normally occurring from northern Argentina to southern United States. However, it has been taken in Indiana (Montgomery, 1930), Kentucky (Williamson, 1899), and Maryland (specimens in the Museum of Zoology, Ann Arbor, Michigan, collected by R. P. Currie). This specimen is similar to those from Florida which I have examined, but is slightly larger than Venezuelan specimens (hw. 20, abd. 17).

124. *Sympetrum ambiguum* Rambur. Middle Bass Island, Lake Erie: 1♂ August 4, 1933. Kelleys Island, Lake Erie: 26♂ and 3♀ August 26, 1933. Indian Lake, Logan Co.: 1♂ August 23, 1934, and 1♂ August 10, 1935. Minerva Lake, Franklin Co.: 1♂ August 3, 1935. Blacklick Woods, Franklin Co.: 1♂ August 16, 1935, W. R. Piper. Blacklick Woods, Fairfield Co.: 1♂ August 16, 1935. Black Lake, Logan Co.: 2♀ August 24, 1935. Lake Loramie, Shelby Co.: 9♂ and 1♀ August 24, 1935. All except the male from Blacklick Woods, Franklin Co., were collected by the writer. This species may be easily differentiated in the field from other species of *Sympetrum* by the conspicuous light green color of the face and the dark markings on the abdomen.

125. *Nehalennia gracilis* Morse. Cedar Swamp, Urbana: 1♂ June 6, 1931, D. J. Borror. Cranberry Bog, Buckeye Lake: 3♂ and 2♀ July 17, 1935, D. J. Borror.

126. *Enallagma boreale* Selys (=*E. calverti* Morse). Sandusky: 2♂ June 20, 1926, B. E. Montgomery (in coll. B. E. M.). Baum-

gardner's Lake, Franklin Co.: 1♂ May 14, 1930, and 1♂ May 24, 1930, D. J. Borror.

127. *Ischnura prognatha* Hagen. Crane Hollow, Hocking Co.: 1♂ April 20, 1930, C. H. Kennedy (DZE).

The 116 species of Odonata hitherto reported from Ohio, with the worker who first reported them (beginning with Kellicott, 1899) are as follows:

1. *Tachopteryx thoreyi* Hagen. Hine, 1925.
2. *Progomphus obscurus* Rambur. Hine, 1900.
3. *Hagenius brevistylus* Selys. Kellicott, 1899.
4. *Ophiogomphus rupinsulensis* Walsh. Kellicott, 1899.
5. *Erpetogomphus designatus* Hagen. Hine, 1913.
6. *Gomphus abbreviatus* Hagen. Hine, 1900.
7. *G. amnicola* Walsh. Hine, 1913.
8. *G. crassus* Hagen. Kellicott, 1899 (as *G. externus* Selys).
9. *G. dilatatus* Rambur. Kellicott, 1899.
10. *G. exilis* Selys. Kellicott, 1899.
11. *G. fraternus* Say. Kellicott, 1899.
12. *G. furcifer* Hagen. Kellicott, 1899.
13. *G. graslinellus* Walsh. Kellicott, 1899.
14. *G. lividus* Selys. Kellicott, 1899.
15. *G. notatus* Rambur. Kellicott, 1899.
16. *G. plagiatus* Selys. Kellicott, 1899.
17. *G. quadricolor* Walsh. Kellicott, 1899.
18. *G. spicatus* Hagen. Kellicott, 1899.
19. *G. spiniceps* Walsh. Kellicott, 1899.
20. *G. vastus* Walsh. Kellicott, 1899.
21. *G. villosipes* Selys. Kellicott, 1899.
22. *G. viridifrons* Hine. Hine, 1901.
23. *Dromogomphus spinosus* Selys. Kellicott, 1899.
24. *D. spoliatus* Hagen. Kellicott, 1899.
25. *Gomphaeschna furcillata* Say. Kellicott, 1899.
26. *Basiaeschna janata* Say. Kellicott, 1899.
27. *Boyeria grafiana* Williamson. Hine, 1913.
28. *B. vinosa* Say. Kellicott, 1899.
29. *Anax junius* Drury. Kellicott, 1899.
30. *A. longipes* Hagen. Kellicott, 1899.
31. *Nasiaeschna pentacantha* Rambur. Hine, 1900.
32. *Epiaeschna heros* Fabricius. Kellicott, 1899.
33. *Aeschna clepsydra* Say. Kellicott, 1899.
34. *A. constricta* Say. Kellicott, 1899.
35. *A. mutata* Hagen. Osburn and Hine, 1900 (as *A. verticalis* Hagen).
36. *A. umbrosa* Walker. Walker, 1912.
37. *A. verticalis* Hagen. Kellicott, 1899.
38. *Cordulegaster erroneus* Hagen. Kellicott, 1899.
39. *C. obliquus* Say. Kellicott, 1899.
40. *Macromia illinoiensis* Walsh. Kellicott, 1899.

41. *M. taeniolata* Rambur. Kellicott, 1899.
42. *Didymops transversa* Say. Kellicott, 1899.
43. *Neurocordulia obsoleta* Say. Hine, 1900.
44. *N. yamaskensis* Provancher. Hine, 1900.
45. *Epicordulia princeps* Hagen. Kellicott, 1899.
46. *Tetragoneuria cynosura* Say. Kellicott, 1899.
47. *Somatochlora hineana* Williamson. Williamson, 1931.
48. *Nannothemis bella* Uhler. Borror, 1930.
49. *Perithemis tenera* Say. Kellicott, 1899 (as *P. domitia* Drury).
50. *Celithemis elisa* Hagen. Kellicott, 1899.
51. *C. eponina* Drury. Kellicott, 1899.
52. *C. monomelaena* Williamson. Kellicott, 1899 (as C. *fasciata* Kirby).
53. *Ladona julia* Uhler. Kellicott, 1899 (as *Libellula exusta* Say).
54. *Libellula* (*Holotania*) *auripennis* Burmeister. Kellicott, 1899.
55. *L.* (*H.*) *cyanea* Fabricius. Kellicott, 1899.
56. *L.* (*H.*) *incesta* Hagen. Kellicott, 1899.
57. *L.* (*H.*) *luctuosa* Burmeister. Kellicott, 1899 (as *L. basalis* Say).
58. *L.* (*Neotetrum*) *pulchella* Drury. Kellicott, 1899.
59. *L.* (*Libellula*) *quadrimaculata* Linnaeus. Kellicott, 1899.
60. *L.* (*Eolibellula*) *semifasciata* Burmeister. Kellicott, 1899.
61. *L.* (*Holotania*) *vibrans* Fabricius. Kellicott, 1899.
62. *Plathemis lydia* Drury. Kellicott, 1899 (as *P. trimaculata* De Geer).
63. *Sympetrum corruptum* Hagen. Kellicott, 1899.
64. *S. obtrusum* Hagen. Kellicott, 1899.
65. *S. rubicundulum* Say (=*S. assimilatum* Uhler). Kellicott, 1899.
66. *S. semicinctum* Say. Kellicott, 1899.
67. *S. verum* Bartenef. Bartenef, 1915.
68. *S. vicinum* Hagen. Kellicott, 1899.
69. *Leucorrhinia intacta* Hagen. Kellicott, 1899.
70. *Pachydiplax longipennis* Burmeister. Kellicott, 1899.
71. *Erythemis simplicicollis* Say. Kellicott, 1899.
72. *Pantala flavescens* Fabricius. Kellicott, 1899.
73. *P. hymenaea* Say. Kellicott, 1899.
74. *Tramea carolina* Linnaeus. Kellicott, 1899.
75. *T. lacerata* Hagen. Kellicott, 1899.
76. *T. onusta* Hagen. Kellicott, 1899.
77. *Agrion aequabilis* Say. Kellicott, 1899.
78. *A. angustipennis* Selys. Hine, 1913.
79. *A. maculatum* Beauvais. Kellicott, 1899.
80. *Hetaerina americana* Fabricius. Kellicott, 1899.
81. *H. titia* Drury (=*H. tricolor* Burm.). Kellicott, 1899 (as *H. tricolor* Burm.).
82. *Archilestes grandis* Rambur. Williamson, 1930.
83. *Lestes congener* Hagen. Kellicott, 1899.
84. *L. disjunctus* Selys. Kellicott, 1899.
85. *L. eurinus* Say. Hine, 1900.
86. *L. forcipatus* Rambur. Kellicott, 1899.
87. *L. inaequalis* Walsh. Kellicott, 1899.

88. *L. rectangularis* Say. Kellicott, 1899.
89. *L. uncatus* Kirby. Kellicott, 1899.
90. *L. unguiculatus* Hagen. Kellicott, 1899.
91. *L. vigilax* Hagen. Kellicott, 1899.
92. *Argia apicalis* Say. Kellicott, 1899.
93. *A. bipunctulata* Hagen. Borror, 1930.
94. *A. moesta* Hagen. Kellicott, 1899.
95. *A. sedula* Hagen. Kellicott, 1899.
96. *A. tibialis* Rambur. Kellicott, 1899.
97. *A. violacea* Hagen. Kellicott, 1899.
98. *Amphiagrion saucium* Burmeister. Kellicott, 1899.
99. *Nehalennia irene* Hagen. Kellicott, 1899.
100. *Chromagrion conditum* Hagen. Kellicott, 1899.
101. *Enallagma antennatum* Say. Kellicott, 1899 (*as E. fischeri* Kellicott).
102. *E. aspersum* Hagen. Kellicott, 1899.
103. *E. carunculatum* Morse. Kellicott, 1899.
104. *E. civile* Hagen. Kellicott, 1899.
105. *E. divagans* Selys. Kellicott, 1899.
106. *E. doubledayi* Selys. Kellicott, 1899.
107. *E. ebrium* Hagen. Kellicott, 1899.
108. *E. exsulans* Hagen. Kellicott, 1899.
109. *E. geminatum* Hagen. Kellicott, 1899.
110. *E. hageni* Walsh. Kellicott, 1899.
111. *E. signatum* Hagen. Kellicott, 1899.
112. *E. traviatum* Selys. Kellicott, 1899.
113. *E. vesperum* Calvert. Kellicott, 1899 (as *E. pollutum* Hagen).
114. *Ischnura posita* Hagen. Kellicott, 1899.
115. *I. verticalis* Say. Kellicott, 1899.
116. *Anomalagrion hastatum* Say. Kellicott, 1899.

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Laboratory Geology

There has appeared another "Laboratory Manual for General Geology." The 31 exercises are distributed as follows: 2 on minerals, 3 on rocks, 12 on topographic maps, 6 on geologic maps, 2 on block diagrams, 1 on fossil plants, and 5 on fossil animals, all with explanations. The author has treated in a rather full manner the material covered in general Geology. The Manual is furnished with the necessary blank pages and tables for student use. There is also available with most exercises additional space entitled "Additional Questions and Instructor's Remarks," a most useful place for recording local geologic phases or conditions. The illustrations are good and the explanations and descriptive material well selected and clear. The manual does not follow any text or lectures although it would of course be best to follow a similar order of presentation in class and laboratory. All pages are scored for easy removal and punched for rebinding.

It is to be regretted that the author does not include, for locating points where he specifies topographic maps, an explanation of the Townships and Ranges printed on many of the United States topographic and geologic maps, although his method will work. An index to the exercises would not be amiss. However, it should prove a usable and convenient manual.—WILLARD BERRY.

Laboratory Manual for General Geology (Physical and Historical), by Mark H. Secrist. xviii+295 pp.; 52 figs., 8 tables, 15 pls. New York, The Macmillan Co., 1935.

Fragmental Rocks

This useful book on fragmental rocks has just reached the reviewer's hands, although it was published in 1931. Professor Tickell, after a short introduction, considers size analysis, then porosity and permeability, the preparation of specimens, the identification of minerals, and the description of minerals found in sedimentary rocks. There are illustrations and tables to explain and supplement the text. It is not a book for those lacking fundamental scientific background, but in the right hands should prove very useful. Sources of methods other than geologic are drawn upon. Hence there are methods developed by hydrologists and ceramists along with geologic methods. The author states that the treatment is "practical rather than theoretical" and such it is. It is most certainly "The Examination of Fragmental Rocks." A bibliography of 108 titles is quite complete and gives sources of information more detailed than in the text. For all who are interested in the make-up of sedimentary rocks it should prove a boon. Petroleum geologists, soil geologists, and others will find it useful.

WILLARD BERRY.

The Examination of Fragmental Rocks, by Frederick G. Tickell. x+128 pp., 51 figs., 18 tables. Stanford University Press, 1931.

STUDIES ON FRESHWATER BRYOZOA. III.

The Development of *Lophopodella carteri* var. *typica*

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INTRODUCTORY

As previously stated in Study I, *Lophopodella carteri* var. *typica* occurs in pond habitats on the under side of *Nymphaea* leaves and on *Vallisneria*, *Elodea*, *Potamogeton* and other pondweeds. It produces reproductive bodies known as statoblasts. These are of one type—free, annulated. They germinate and give rise to new colonies. Colonies of this form were collected at Squaw Harbor (Put-in-Bay) and East Harbor in the southwestern part of Lake Erie and taken into the laboratory. Their behavior under laboratory conditions was noted. Their released statoblasts were collected and in time germinated. The growth and development of the resultant colonies and their production of another crop of statoblasts was carefully noted and recorded. Since the observations were made on living material, no attempt will be made in the present study to discuss the histology of the various processes.

METHODS

In collecting, the colonies were either gently taken off the lily pads or lily stems with a scalpel blade or else the whole lily pad was brought into the laboratory and the colonies left undisturbed on it. They were kept in fresh lake water in fingerbowls. The water was changed daily to insure sufficient food supply and proper conditions for the polypides. As statoblasts were released by the colony they were put into a Syracuse watch glass (with water) until the time of germination. After germination, the watch glasses with the germinating statoblast or polypide were immersed in a finger bowl. This made possible microscopic study of the zooecia with the least disturbance.

Colonies which were collected during the summers of 1932 and 1933 were kept in the Stone Biological Laboratory—not

far from the collecting site—and later (in September) transferred to the laboratory at Ohio State University (Columbus, Ohio). Their behavior and development under laboratory conditions was studied until the succeeding summers. The animals were kept alive with at first daily, then twice weekly, changes of medium. The medium in which these animals were kept was simply greenhouse tank water and some organic debris from around the bases of aquatic plants which were grown in the greenhouse tanks. Some of the organisms which occurred in the water were Planaria, Ostracoda, Copepoda, Oligochaeta, Rotifera, Gastropoda and Protozoa, in addition to plant material.

OBSERVATIONS

Colonies of *L. carteri* were collected during the entire summer season. The earliest date for the finding of mature statoblasts was July 20 (1933). After that time they were found in almost every collection. However, in the 1932 collections (from Squaw Harbor) no mature statoblasts were recovered from the colonies until September 24 although developing statoblasts were found as early as August 19. The latest day for release of statoblasts in the laboratory from the comparatively small number of colonies of the 1932 collections was November 22. Statoblast germinations occurred from November 19, 1932, until the supply of statoblasts was exhausted (February 9, 1933). The succeeding year, germinations were continuous until the end of March, when observations were discontinued.

THE DEVELOPMENT OF A COLONY FROM A STATOBLAST

The dormant period of statoblasts has been given attention by relatively few workers—Braem, Brooks, Brown, Graupner, Kraepelin, Marcus, Oka and Wesenberg-Lund. These workers have given some very interesting observations on germination and dormancy of statoblasts of some of the following species: *Plumatella repens*, *P. coralloides*, *Cristatella*, *Fredericella*, *Pectinatella magnifica* and *Pectinatella gelatinosa*. Some workers insisted that freezing was necessary before the germination of statoblasts. Others believed that that was not necessary. The length of the rest period is also variously given. Brown (1933) has given a very good account of germinations under various conditions. Brooks (1929) concluded that *Pectinatella*

"statoblasts develop steadily from the time they are formed until the polypides are fully formed, just as buds do." This conclusion came as a result of observations upon the germination of statoblasts under different temperature and environmental conditions. A similar condition exists in *Lophopodella*, at least as concerns those statoblasts which developed in the laboratory. Statoblasts of *L. carteri* var. *typica* which were collected or which developed from the August 25, 1933, collection have hatched continually until the termination of observations—March 22, 1934, and there still remained a large number which might have hatched had they been permitted to develop to the proper stage.

The rest or dormant period of a statoblast is interpreted as the period between its release and its germination. Brown (1933) defined germination as the separation of the two valves and the protrusion of the polypide. Rest periods of *L. carteri* statoblasts varied from 34 to 137 days. The germination of these reproductive bodies was undoubtedly hastened by the subjection to laboratory temperature conditions. Figures for statoblasts under natural conditions of extremes of temperature would probably be considerably different.

GERMINATION

The first visible indication that a statoblast is ready to germinate is the splitting of the chitinous processes at the extremities of the valves and the appearance of crooked dark ridges on the capsule surface. The splitting is first noted at the tips of the processes. This continues to the base of the spines, then the valves also begin to split. The peculiar nature of the spined processes is clearly shown when they have split, for it is then that one notices that the barbs of the processes of one valve do not correspond to or coincide with the barbs of the corresponding processes on the other valve. This splitting process may take considerable time, more than a week, but just how much longer has not been determined.

After the valves have split to a slight degree, the embryo may be seen as a rounded ball or mass of tissues, grayish-white in color. The length of time which is required before this mass of tissues becomes a full-fledged polypide depends upon a great many factors such as the potentialities inherent within the statoblast, the nature of the medium in which the statoblast germinates, the temperature and other physical and biological

factors. Under unfavorable conditions, this mass of tissue never reaches the polypide stage but simply degenerates. For the past two years I have been unable to rear colonies from statoblasts which have hatched late in the year (November and December). However, those which germinated in January, February and March produced colonies. The failure in the first instance may have been due to improper care or to the fact that some of the statoblasts germinated prematurely and the polypides lacked sufficient vitality to carry them through the budding stages. However, this is merely supposition.

The time required before this ball of germinating tissue protrudes as a contractile and motile structure from between the valves is very short. It may be only a day or two, depending upon the factors previously mentioned. For want of a more descriptive term I shall use the term employed by Brooks—("mucous pad")—for this protruding structure. (Brooks used the term in connection with *Pectinatella.*) When this first appears, it can be divided into two distinct areas—an outer, clear whitish cellular rim and the remaining denser, grayish, more granular, inner portion. The distinction between these two areas is more marked in the early stages of the polypide than in the more advanced stages. This basal portion is very contractile and adhesive. If it is watched for a period of time, undulations, contractions or occasional movements may be observed. By this structure the polypide and the valves of the statoblast are attached more firmly to the substratum. This portion of the body wall may change its shape from an indefinite rounded mass to a finger-like projection or to a bi- or tri-lobate protrusion. It is very turgid, resembling a collodion sac filled with liquid.

As yet, the valves of the statoblast are quite close together. In the meantime the polypide is developing between the valves, hidden from view.

The polypide protrudes its tentacles beyond the edge of the valves in about two or sometimes three days after the "base" has appeared. The polypide is apparently well developed but still not fully grown. Its tentacles are much shorter than those of an adult. The same fact holds for the digestive tract. The distance from the lophophore to the invaginated fold is much smaller than in the adult. Even the number of tentacles may be fewer in the young than in the mature polypide.

If one observed the individual very closely and under proper illumination one can see the very delicate transparent ectocyst. It terminates at the invaginated fold. When the individual moves or contracts, the ectocyst is thrown up in a number of wrinkles or folds.

As the polypide continues to develop and enlarge, the valves of the statoblast are pushed farther and farther apart. The base begins to lose its distinctive appearance and gradually becomes more and more like the remainder of the polypide.

BUDDING

Brooks (1929) attempted to rear *Pectinatella* polypides, noting that they lived for two weeks upon yolk material and that they could be kept alive for six weeks but that they remained as single polypides instead of forming colonies. The trouble may have been with the food supply, because in the case of *Lophopodella*, as soon as the food supply was increased and the right kind of food used, the polypides began to multiply in number.

In the case of *Lophopodella* very complete records were kept of two colonies in particular, although a number of others were watched less closely. For convenience, we shall call these two colonies *A* and *B*. These colonies were all of the second generation, that is, were hatched from statoblasts which came from the colonies collected in Squaw Harbor.

Table I gives the number of individuals which were present in each colony at any particular time.

The interval between germination of a statoblast and the evagination of the second polypide is relatively long—19, 21, 38, and 43 days (figures for four colonies). The interval between the evagination of the second and third polypides was 8 days for Colony *A* and 3 days for Colony *B*. The intervals between the third and fourth polypides was 2 days for *A* and 3 days for *B;* between the fourth and fifth polypides, 4 days each for *A* and *B;* between the fifth and seventh polypides, 3 days for *A* and 1 day for *B;* between the seventh and eighth polypides, 1 day each for *A* and *B;* between the eighth and twenty-seventh polypides, 7 days for *A* and 8 for *B;* between germination and the thirty-seventh polypide of Colony *B* and between germination and the forty-fifth polypide of Colony *A* was 68 days and 70 days respectively.

TABLE I

Date	Rate of Budding		Statoblasts Released	
	Colony *A*	Colony *B*	Colony *A*	Colony *B*
	Number of individuals	Number of individuals		
I– 7–1933	Just hatched			
I– 9	1	Just hatched		
II–14	2	1		
II–21	2	2		
II–22	3	2		
II–24	4	3		
II–27	4 plus 3 buds	4		
II–28	5	4		
III– 1	5	4		
III– 3	7	5		
III– 4	8	7		
III– 5	12	8		
III– 6	13	9		
III– 7	15; statoblasts developing	10		
III– 8	20	14, statoblasts developing		
III– 9	24; about 9 statoblasts developing	16		
III–10	25	18		
III–11	27	22		
III–13	32, numerous statoblasts in colony, some with a dark brown central capsule	27		
III–14	40, colony distinctly tri-lobate	32; colony tri-lobate, one lobe showing signs of subdivision		
III–15	42; three main lobes in colony, each subdivided into two; about 24 developing statoblasts	33		
III–16	43, four main lobes	34		
III–17	44	34		
III–18	45; many statoblasts present in colony	37.		
III–19	44; colony divides into two colonies; one polypide degenerated after the division	37; colony in five lobes, ready to divide	2	2
III–20		Colony divided in two		
III–21	One colony divided		1	1
III–22			1	
III–23		Another division		
III–24			3	
III–27			8	3
IV– 3			16	8
IV– 4			3	
IV– 6				1
IV–6 to V–25			6	1
V–31				1
VI–19	The *A* and *B* colonies, some of their statoblasts and some young colonies which had hatched between April 8 and June 18, 1933, from some of the statoblasts produced by Colonies *A* and *B* were transferred from the Zoology laboratory in Columbus, Ohio, to the Stone Biological Laboratory on Lake Erie.			
VI–20	The colonies did not survive the rough handling en route.			

Approximately 58 and 59 days elapsed between the germination of the statoblasts which produced Colonies *A* and *B* and the appearance of young, developing statoblasts in the two colonies. Exactly 40 days later (on the 89th day of the existence of Colony *B*) three statoblasts of Colony *B* germinated in the laboratory. The first statoblasts of Colony *A* to germinate did so when the colony was 110 days old. Of the 40 statoblasts produced by Colony *A*, 15 germinated between April 27 and June 18, 1933. Of the 17 produced by Colony *B*, 9 germinated between April 8 and May 15.

Although Colony *A* hatched two days before *B* and showed developing statoblasts earlier, these statoblasts did not begin to germinate until over three weeks after the first ones of Colony *B* had germinated. This is most likely a matter of individual variation.

The foregoing account has dealt principally with the asexual form of reproduction in this variety. Sexual reproduction needs careful study in order to make the life cycle story complete.

CONCLUSIONS

1. *Lophopodella carteri* var. *typica* was observed through two generations and to the beginning of the third, in the laboratory.

2. Careful accounts were kept of the development of two colonies in particular—the date of their germination, the time intervals between evagination of succeeding polypides and the rate of development, release and germination of statoblasts from these colonies.

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EXPLANATION OF PLATES

Plate I

Fig. 1 Two developing statoblasts in a colony of the August 29, 1932, collection.

Fig. 2. Side view of the statoblasts pictured in Fig. 1.

Fig. 3. The statoblasts in a slightly more advanced stage.

Fig. 4. A later stage in the development of a statoblast. The statoblast was drawn on October 17, 1932, and shows the lobate edges of the float. The edges had not as yet sufficiently differentiated to show the characteristic barbed processes. There were eight lobes on one side and nine on the other in this particular specimen.

Fig. 5. A still later stage in the development of a statoblast. This diagram shows a thin gelatinous covering or sac investing the statoblasts. Several statoblasts with such an investment were observed in late October in colonies of the September 25, 1932, collection. The processes at the ends are well differentiated.

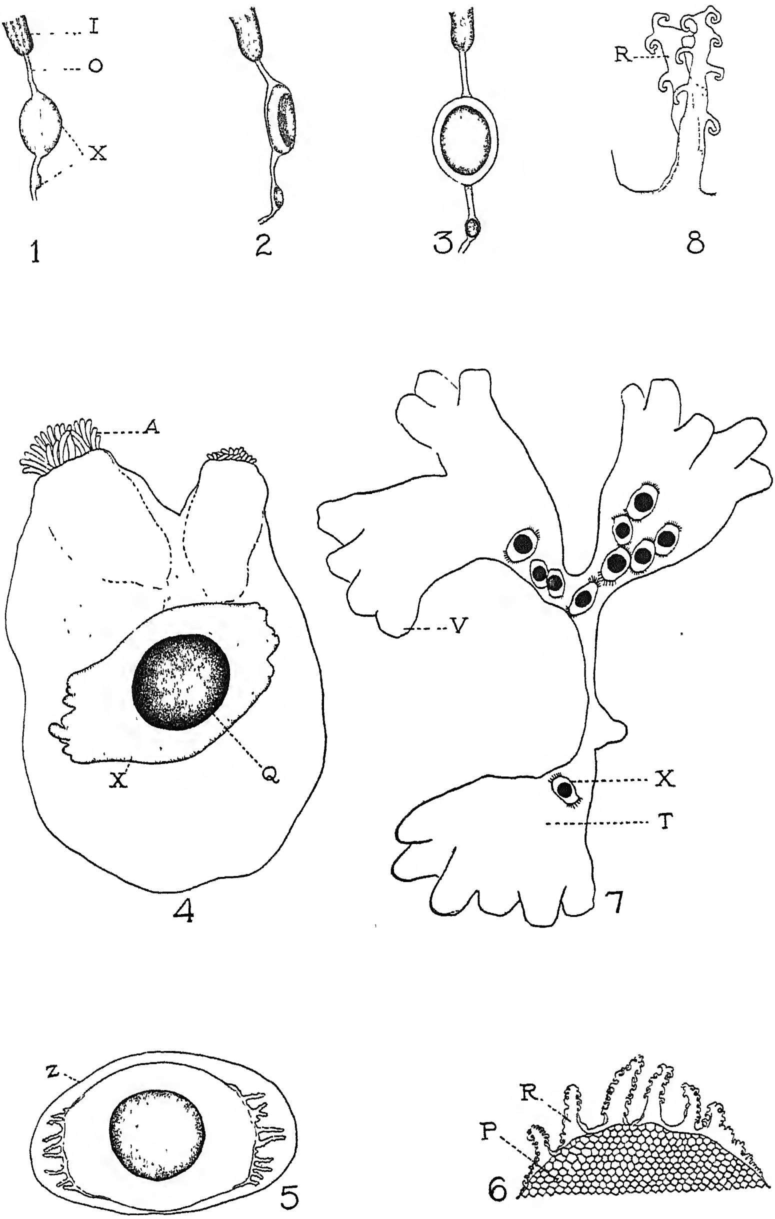
Fig. 6. A statoblast end bearing the barbed processes. The air cells of the float are also shown.

Fig. 7. A sketch of Colony *B* just preceding division. The statoblasts are shown as being somewhat concentrated in two lobes. To simplify the drawing, the polypides are roughly figured in the retracted state. The strip of coenoecial tissue connecting the three lobes becomes narrower and longer, due to the muscular activity of the polypide, particularly of the muscles of the body wall, until eventually, the connection breaks and the colony has divided into two parts.

Fig. 8. An enlarged view of the splitting of a barbed process at the extremity of the statoblast. The barbed process when superficially observed appears single but closer inspection shows that it is composed of two similar halves, one-half from each valve, and that the barbs of the halves do not necessarily coincide, but that there may be some overlapping.

ABBREVIATIONS

A—Ciliated tentacles.
B—Lophophore.
C—Tentacular crown.
D—Region of anal opening.
E—Rectum.
F—Esophagus.
G—Tentacular sheath.
H—Invaginated fold region. Musculature omitted.
I—Stomach.
J—Bud.
K—Retractor muscles.
L—Ectocyst.
M—Endocyst.
N—Body wall.
O—Funiculus.
P—Float.
Q—Capsule.
R—Barbed processes.
S—Statoblast valve.
T—Coenoecium.
U—Lobe.
V—Zooecium.
W—Epistome.
X—Statoblast.
Y—Temporary base or "mucous pad" (Brooks).
Z—Gelatinous covering.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EXPLANATION OF PLATES

Plate II

Fig. 1. Colony *B* three days after hatching (hatched on February 9. 1933). The basal part is contractile and motile; yolk granules present.

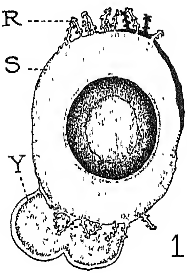
Fig. 2. Colony *B* as it appeared on February 13, showing the protruding tentacular crown of the first individual. When the surroundings were disturbed, the polypide quickly withdrew from sight between the two statoblast valves.

Fig. 3. Colony *B* on February 14. The tentacles numbered 52 in *B* and 56 in *A* at this time. This view of the tentacular crown shows the relative lengths of the tentacles on the arms of the lophophore and about the oral region at this particular stage. The epistome is evident although the mouth is not shown clearly. A number of features of the polypide are omitted in the figure, the purpose of the sketch being merely to show the growth of the colony.

Fig. 4. Colony *A* as it appeared on February 1, 1933. It was hatched on January 7. A developing bud is shown in the body wall. The statoblast valves remained attached to the polypide until February 18. Older zooecia differ from the young in having longer tentacles, a larger lophophore, a longer digestive tract and a greater length of polypide between the lophophore and the invaginated fold. The ectocyst is shown as the outer extremely delicate and transparent membrane.

Fig. 5. A small colony, showing the general arrangement of the zooechia. Not all polypides can be shown from any one angle of observation, hence, there are more polypides present in the colony than pictured. In this figure, the tentacular crowns have been cut away and the internal organs of the polypides have been omitted for the sake of clarity.

(See page 464 for Explanation of Abbreviations)



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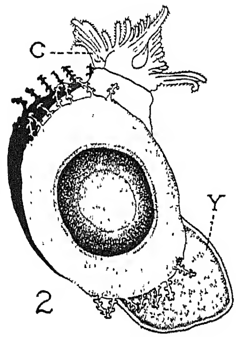

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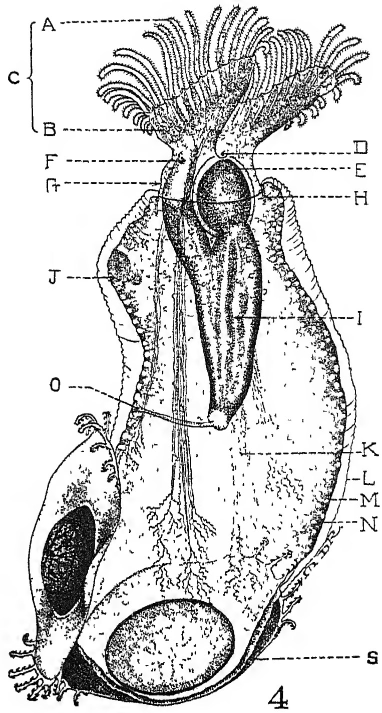

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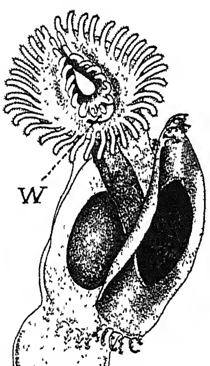

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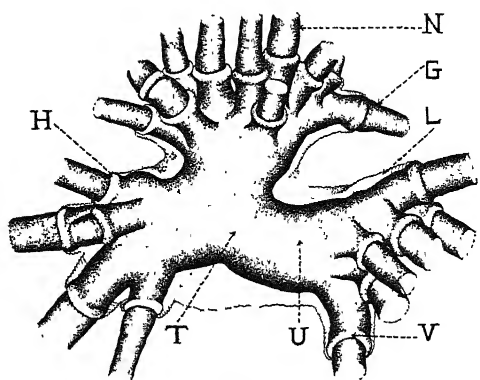

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BOOK NOTICES

Primate Evolution and Its Anatomical Evidence

Man's zoological position as a species is a question which always claims human interest. It will continue to be a source of speculation awaiting the day when his history recorded in fossil and artifact will have been fully disclosed.

"In order satisfactorily to study the specific problem of Man's phylogenetic origin, it is essential to visualize in proper perspective the evolutionary development of the whole group of Primates of which he is but one member."

Thus Professor Clark introduces a detailed description of the comparative anatomical and paleontological evidence which forms an essential basis of speculation on the phylogenesis of the Primates. Separate chapters are devoted to the evidence of the skull, the teeth, the limbs, the brain and special senses, the digestive, and the reproductive systems. Fossil material is described and compared with modern Primates. The author has brought together a great deal of knowledge of the anatomy of living Primates, much of which is the result of recent studies. The last chapter is a summary supplemented by useful charts showing the main morphological trends in the Lemuroidea, the Old and New World Tarsioidea and the Anthropoidea. Thus man is seen to comprise only one family in the large, divergent, and ancient order of Primates.

This book should prove invaluable to the Anatomist, the Anthropologist, and the General Zoologist as an authentic and comprehensive source book in its field.—JOHN W. PRICE.

Early Forerunners of Man, by W. E. LeGros Clark. xvi+296 pp. Baltimore, William Wood and Co., 1934.

Sahara

To most of us the term "desert" conotates something of Oriental mystery and strangeness; hence we should find much of interest in the recent translation by Dorothy F. Mayhew of E. F. Gautier's work, "Sahara, the Great Desert." Gautier explains the unique setting of the Sahara, which covers many more degrees of longitude than degrees of latitude, and has a peculiar climate which influences desert life. The geography and the geologic history since the close of the Tertiary is discussed. Here the influence of the "pre-desert" drainage on the present geographic organization on life is shown. Various regions are discussed in more detail to bring out the vivid difference between "normal" humid regions and the desert life. The influence of the Nile on the Sahara is clearly explained, it being the only river crossing this human barrier. The book is in reality a manual of geography and Quaternary geology for this great arid area which in the geologic past was not a dessicated region.

The volume is concise almost to the point of being abrupt, but for all that, is very readable and interesting. Of the 32 illustrations 6 are small maps or block diagrams showing various local details such as stream capture and the like. A map of the Sahara on the scale of about 220 miles to the inch, is folded in. This map shows sand dune areas and regions elevated 1,600 to 5,000 feet, 5,000 to 10,000 feet and over 10,000 feet, as well as tours, railways and wells (important in such dry regions).

This authorized English translation has incorporated in it much additional material which Professor Gautier has accumulated since the first appearance of "Le Sahara" in 1928. The Columbia University Press has given us a well-handled book, Miss Mayhew a fine translation, and Professor Gautier an interesting and valuable work on this great region.—WILLARD BERRY.

Sahara, the Great Desert, by E. F. Gautier (translated by Dorothy F. Mayhew). xviii+264 pp. New York, the Columbia University Press, 1935.

Principles of Insect Morphology

On rare occasions there appears in a given scientific field an outstanding masterful presentation of the subject matter in the form of a book. Recently a book of this character has appeared in the field of entomology, namely, "Principles of Insect Morphology," by R. E. Snodgrass, of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine. An examination of the book soon reveals its outstanding features. It is an exhaustive compilation of the best literature on the subject and also includes a great deal of original information. Without much doubt the publication will prove to be an excellent reference for entomologists, particularly for those conducting investigations on external or internal anatomy of insects.

One of the remarkable features of the book is the presence of numerous, clear-cut and beautifully labelled drawings. These add greatly to a clear understanding of the discussions. The book presents an introductory chapter, a concise chapter on embryology and development, nine chapters on external morphology, and eight chapters on internal morphology. At the ends of many chapters an excellent glossary of terms has been included. It is the personal opinion of the reviewer that a general glossary at the end of the book would have been more convenient.

All libraries possessing entomological literature and students and investigators in entomology should possess, or have access to, this excellent publication.

A. Peterson.

Principles of Insect Morphology, by R. E. Snodgrass. xix+667 pp. New York and London, McGraw-Hill Book Co., 1935.

Dynamical Meteorology

Professor Brunt divides his recent book into twenty chapters with a total of some 208 sections. The first chapter gives the facts which call for explanation. The second deals with certain statistical and thermal relationships. Chapter three deals with damp air, while four handles thermodynamics of the atmosphere. Radiation is considered in chapter five and radiation in the troposphere in the sixth. Radiative Equilibrium and the stratosphere are discussed in the seventh chapter. Chapters from eight on consider such subjects as general equations of motion, motion under balanced forces, surfaces of discontinuity, winds, turbulences, eddies, classification of winds, life-history of surface air currents, the polar front and cyclones, anticyclones, and general circulation. Some idea of the physical (and mathematical) side of the book can be gotten from the number of mathematical equations in the first 16 chapters, there being some 567 major ones.

This is not an elementary volume on meteorology but rather one for advanced students who have sufficient physical background to enter upon the theoretical field. The professional meteorologist will find much of interest here.

The 112 figures, ranging from autographic records to polar projections showing temperature and pressure, are carefully selected and very clear. Professor Brunt's style is direct, making for easy reading. As would be expected, the volume uses mostly British or European examples for small areas. It fills a place which, as far as I know, has not previously been filled in English-speaking countries.

Willard Berry.

Physical and Dynamical Meteorology, by David Brunt. xxii+411 pp. Cambridge, at the University Press. New York, The Macmillan Co., 1935.

Physics from Then until Now

This book gives to the layman a very graphic and fascinating account of the development in physical science from its beginning in pre-Greek times to the modern era. It can be recommended to readers who have only a small knowledge concerning this subject and is especially suitable as a text for introductory and survey courses for college students desiring to visualize what has been the purpose and scope of physical science.—H. H. Nielsen.

The Rise of Modern Physics, by Henry Crew. Second Edition, revised and enlarged. xix+434 pp. Baltimore, The Williams and Wilkins Co., 1935.

Pyrethrum

Beginning with a history of the production and manufacture of pyrethrum products this interesting discussion treats of the growing, cultivating, harvesting and marketing of the plant and its products. The insecticidal or active principle is then discussed and the methods used to evaluate the insecticidal value both chemically and biologically. The comparative value of various commercial grades of pyrethrum is discussed, the effect of storage, light and heat upon the reduction of the active principle and the manufacture and production of different types, grades and extracts. The latter portion deals entirely with the uses of pyrethrum as an insecticide in connection with various types of insects such as live stock, household, horticultural and other insect pests. This portion contains the results of the more important research work. An excellent bibliography containing some six hundred references is appended.

This is a valuable reference book for students who are interested in methods of insect control.—DWIGHT M. DELONG.

Pyrethrum Flowers, by C. B. Gnadinger. xi+269 pp. Minneapolis, McGill Lithograph Co., 1934.

Man and His Future

The British have pioneered in the field of popularizing science, and now the author of "The Mechanism of Creative Evolution" has joined the parade. This new little volume from his pen brings genetics to the general reader in most interesting and readable form. An intriguing opening chapter on the mystery of life is followed by the usual account of Mendel's work and the principles of heredity. Several chapters on genes and the gene complex give the author an opportunity to exercise his sense of the dramatic. The discussion of genes leads naturally into an account of evolutionary processes, past and present. This in turn opens the door to a discussion of possible trends in evolution in the future. Here the author gives his imagination full rein, and the ensuing speculations are thought-provoking, to say the least. The book can be read in an hour, and it will be an hour well spent.—L. H. S.

Heredity and the Ascent of Man, by C. C. Hurst. ix+136 pp. Cambridge, England, at the University Press. New York, the Macmillan Co., 1935.

Quantum Mechanics

This is a textbook especially useful for and adaptable to the needs of the experimental physicist. The mathematical prerequisites are kept to the absolute minimum, the requirements being only a working knowledge of calculus and differential equations. After an introduction to the principle of the quantum mechanics, it is applied to many important problems of especial interest to the chemist and physicist, the solution to the Schrodinger equations being carried out in scrupulous detail. Of especial value are the many tables and appendices found throughout and at the end of the book.—H. H. NIELSEN.

Introduction to Quantum Mechanics, by L. Paulding and E. B. Wilson, Jr. xiii+468 pp. New York, McGraw-Hill Book Co., 1935.

Oriental Scutelleroidea

One might judge from the title of this work that it would be a rather dry subject to review, but it is, in fact, much more than a faunal catalogue since the author discusses the faunal relations and derivations in such manner as to make it a distinct contribution to zoogeography. There is an introduction of nine pages discussing the sources of information and the general faunal areas, a catalogue occupying 168 pages, and annotated bibliography which is very complete and occupies seventy pages, the whole volume consisting of iv and 294 pages.

The distinctly interesting geographic section is included in his discussion of the faunal regions and these are given as (1) Indo-China which includes South China and Formosa, (2) Manchurian, including North China, Manchuria and Korea, (3) Indian, including India proper, (4) Ceylonese for the Island of Ceylon, (5) Malaysian, including Malay Peninsula and adjacent islands, (6) Philippine,

(7) Austro-Oriental, including most of the East Indian Archipelago, (8) Japanese, and (9) Siberian, including Mongolia, Tibet and Sinkiang. In discussing these inter-relationships of faunae Dr. Hoffman has been wisely conservative in the omission of any final conclusions or deductions, evidently appreciating the uncertainty of positive conclusions in a region where there has been so much opportunity for intermigration. Such a group of insects, however, is perhaps less affected by migrations than many other groups, but it would seem that there is a fair agreement with the faunal areas that have been indicated for such vertebrate groups as birds and mammals which, of course, have been much more thoroughly studied than the insects.

The work is a good example of typography, corresponding with the Journal of the Lingnan University of which this is a Science Bulletin. It is certainly a very commendable contribution to our knowledge of a little known region.

H. Osborn.

An Abridged Catalogue of Certain Scutelleroidea (Plataspidae, Scutelleridae, and Pentatomidae) of China, Chosen, Indo-China, and Taiwan, by William E. Hoffmann. iv+294 pp. Lingnan University, Canton, China, 1935.

Life Relations of Algae

This book attempts to present in as simple a fashion as possible the author's conception of an orderly arrangement of algological material about which "any desired course may be planned." After a chapter on the classification of algae "based on evolutionary development, with special reference to pigmentation and food reserves," the major portion of the book (some 400 pages) is given over to a systematic treatment of the Cyanophyceae (Myxophyceae), Rhodophyceae, Phaeophyceae, Chrysophyceae and Chlorophyceae, with complete description to genus. A novel feature is the inclusion of a number of life cycles and descriptions of plants other than algae presented as bases of comparison with those of algae.

The five major groups of marine algae are considered as radically different from each other especially in the matter of pigmentation. The course followed in their evolution represents a parallel development of types. The author believes that "the factor of illumination has been and is the primary force in determining the present distribution of marine algae." On this assumption the blue-green algae developed originally at a time of very weak light, known as the Cyanophycean period. As stronger and stronger rays of light penetrated to the earth there occurred the Rhodophycean period, the Phaeophycean period, the Chrysophycean period, and finally the Chlorophycean period. The first four periods arose in the archaeozoic era, and the last one in the proterozoic.

The last three chapters discuss in order "The Problem of Algal Control," "The Algal Food of Animals," and "Marine Algae, Our Richest Source of Vitamins: Algae as Food for Man."

As one might expect, knowing the author's long years of study of the algae of the Pacific, the point of view is that of a Marine Algologist. Teachers not proficient in Latin and Greek will welcome the careful attention paid to the etymology of generic terms. An appendix is devoted to the "Standardization of Method of Drawing Algae for Publication." The illustrations and diagrams in most cases are presented on a large scale. An extended bibliography and a good index complete the book.—L. H. Tiffany.

The Algae and Their Life Relations, by Josephine E. Tilden. xii+550 pp. Minneapolis, The University of Minnesota Press, 1935.

Physical Principles

A new and very useful textbook suitable for an introductory course in physics for college students. In its mathematics prerequisite the book is very modest, and in it is incorporated the desirable idea of introducing as early as possible important concepts from modern physics. In the last chapters especially, several of these topics are expanded upon in some detail. The book contains throughout many clarifying illustrations and a great many excellent problems are available for student use.—H. H. Nielsen.

College Physics, by Mendenhall, Eve and Keys. x+592 pp. Boston, D. C. Heath and Co., 1935.

Learning Physiological Principles

This is an excellent laboratory guide for the training of students in the drinciples of physiology. Emphasis is placed upon the critical evaluation of the results of experiments, the drawing of suitable inferences, and the application of the principles involved. The distinction between actual objective data and the principles and inferences accruing from such data is an important one, and the authors have been careful to observe the distinction and train the student to observe it. The book is well and thoroughly illustrated. Of especial value is the appendix, containing information on the preparation of materials, the methods of chemical procedure, and the dosages of drugs for various experimental purposes.

L. H. S.

Experimental Physiology, by Maurice B. Visscher and Paul W. Smith. 191 pp., 75 fig. Philadelphia, Lea and Febinger. 1935.

Minerals for the Beginner

Someone looking for a simple beginning book for those who are interested in minerals and who lack formal training will welcome this little volume. Dr. Hawkins tells what minerals are and how to find and collect them. He discusses the types one is likely to find in various kinds of quarries. Finally (and this takes up most of the book) he describes some 187 minerals. A short bibliography and an index close the book.

The book is not exhaustive and makes no pretense of being so. However, for beginners or those interested as amateurs it is a good introduction.

Willard Berry.

The Book of Minerals, by Alfred C. Hawkins. xii+161 pp. New York, John Wiley & Sons, 1935.

King's Bay

On the west coast of Spitsbergen in latitude 790 N. is situated a region of very interesting geology and complicated structure. The desire for information on the area due to the presence of coal resulted in the excellently arranged, well written and careful study of the geology of the King's Bay region.

In the area are found, from the oldest to the youngest, the following sections: basal granites overlain by the Hecla Hoek series of Ordovician age or older, composed of limestones, dolomites, quartzites and mica shists, upwards of 6000 meters thick. Overlying these in angular unconformity are Devonian conglomerates, sandstones and shales of about 300 m., and in places by some 100 m. of lower Carboniferous beds. These last two are overlain unconformably with middle and upper Carboniferous (450 m.), littoral and marine limy beds, with a Cyathophyllum limestone at the top. Some 250 m. of chert and cherty beds above the Cyathophyllum limestone are referred to upper Carboniferous and Permo-Carboniferous. Above these is a 40 m. layer of glauconite, green sandstone. Overlying unconformably these series of older rocks are a series of shales and clays, the Bottom shales, some 50 m. thick, which are referred to the Cretaceous. Conformably above them are some 200 m. of conglomerates, sandstones, shales and coals of Paleocene and possibly Eocene age. The six workable coals occur in this series. It is estimated that the seams contain 16.2 million tons, of which 6.58 million are workable. The coal was discovered in 1610 by English whalers, production began in 1916 and continued to 1929 when a slump in prices and an accident caused a shut-down. The mines are now full of ice, but a watch is maintained on the properties. The structure is rather complicated; much of the folding is late Tertiary.

This is an excellent memoir, well written (in English) and well illustrated. It is a valuable contribution to the geology of high latitudes.—Willard Berry.

Geology of the King's Bay Region, Spitsbergen, with special Reference to the Coal Deposits, by Anders K. Orvin. 195 pp. Skrifter om Svalbard og Ishavet, No. 57. Oslo, 1934.

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